POPULATION ECOLOGY, DAMAGE EXTENT OF MAJOR INSECT PESTS AND MANAGEMENT APPROACHES FOR JHUM AND RICE-COTTON INTERCROPPING IN CHOTTOGRAM HILL TRACTS OF BANGLADESH

MD. AHSANUL HAQUE

A DISSERTATION
FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY
IN
THE DEPARTMENT OF ENTOMOLOGY

DEPARTMENT OF ENTOMOLOGY
SHER-E-BANGLA AGRICULTURAL UNIVERSITY
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By

MD. AHSANUL HAQUE

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Certificate of Approval

....
Prof. Dr. Md. Abdul Latif
Chairman and Supervisor
Advisory Committee

....
Prof. Dr. Md. Razzab Ali
Member
Advisory Committee

....
Prof. Dr. Md. Mizanur Rahman
Member
Advisory Committee

....
Prof. Dr. Md. Rafiqul Islam
Member
Advisory Committee

DEPARTMENT OF ENTOMOLOGY
Sher-e-Bangla Agricultural University (SAU)
Sher-e-Bangla Nagar, Dhaka-1207

CERTIFICATE

This is to certify that the Dissertation entitled "**POPULATION ECOLOGY, DAMAGE EXTENT OF MAJOR INSECT PESTS AND RICE-COTTON INTERCROPPING IN CHOTTOGRAM HILL TRACTS OF BANGLADESH**" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **DOCTOR OF PHILOSOPHY in THE DEPARTMENT OF ENTOMOLOGY,** embodies the result of a piece of *bonafide* research work carried out by **MD. AHSANUL HAQUE**, **Registration No. 14-06366** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledged by the Author.

Dated: June 30, 2019
Dhaka, Bangladesh

Prof. Dr. Md. Abdul Latif
Chairman and Supervisor
Advisory Committee
Department of Entomology
SAU, Dhaka

ABBREVIATION AND SYMBOLS

°c	Celsius or Centigrade temperature
µg/g	Microgram per gram
Min.	Minimum
Max.	Maximum
App.	Appendices
Approx.	Approximately
mm	Millimeter
mg/kg	Milligram per kilogram
Ton per hectare	t/ha, tha^{-1}
cm	Centimeter
ml	Milliliter
Kg/ha	Kilogram per hectare
BARI	Bangladesh Agricultural Research Institute
BSMRAU	Bangabandhu Sheikh Mujibur Rahman Agricultural University
CDB	Cotton Development Board
CHT	Chittagong Hill Tract, Chottogram Hill Tract
BRRI	Bangladesh Rice Research Institute
FAO	Food and Agriculture Organization
BARC	Bangladesh Agricultural Research Council
SRDI	Soil Resource development Institute
UNDP	United Nations Development Programme
BSCIC	Bangladesh Small and Cottage Industry Corporation
KGF	Krishi Gobesona Foundation
ICAR	Indian Council of Agricultural Research
CDI	Crop Diversity Index
CI	Cropping Intensity
CV	Coefficient of Variation
ANOVA	Analysis of variance
Sd	Standard Deviation
RCBD	Randomized Complete Block Design
SD	Honest Significance Test
OM	Organic matter
FPs	Farmers' practices
BSFB	Brinjal Shoot and Fruit Borer
OSFB	Okra Shoot and Fruit Borer
SA	Scientific Assistance
SC	Shifting Cultivation
SAAOs	Sub Assistance Agricultural Officers
RH	Relative Humidity
viz.	Namely (is short for the Latin videlicet)
etc	Et cetera

ABBREVIATION AND SYMBOLS

@	**at a rate of**
WG	**Wettable Granules**
EC	**Emulsifiable concentrates**
®	**The registered trademark symbol**
SC	**Soluble Concentrates**
M	**Million**
Kcal	**Kilo Calorie**

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SAU, Dhaka

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POPULATION ECOLOGY, DAMAGE EXTENT OF MAJOR INSECT PESTS AND MANAGEMENT APPROACHES FOR JHUM AND RICE-COTTON INTERCROPPING IN CHOTTOGRAM HILL TRACTS OF BANGLADESH

ABSTRACT

The study comprised four experiments conducted at four separate trials at jhum and intercrop fields in different hills of Bandarban, Rangamati and Kagrachari during March 2014 to February 2016 to find out insect pests of existing cropping system, identify common insect pests their population dynamics and extent of damage in addition evaluate effective pest management approaches for jhum and rice-cotton intercropping system at hill region of Bangladesh. The field experiments were conducted in RCBD from farmer's field of jhum and rice-cotton intercropping on hill during April 2015 to January 2016. Among the 150 farmers, average, 19.33% received pest management and other training whereas 80.67% did not received any types of training. Jhumian people were used to their traditional practice to suppressed pest and diseases. Forty eight insect mite pests on rice, country bean (22), hill sesame (30), cowpea (17), yard long bean (16), marpha served as (18), okra (13), eggplant (24), chili (11), maize (12), roselle (6), whereas cotton plant serve as a host for an extensive range of insect mite (45) similar to rice. Among them leaf webber on sesame**,** BSFB on eggplant, fruit flies on marpha and cucumber, mite and thrips on chili and red cotton bug on cotton were reflected as major insect mite pests. Nonetheless phloem-feeders bugs, aphid, jassid, whitefly, leaf feeding epilachna beetle and grasshoppers were abundance extent of damage were maximum on different jhum crops and intercrops thus considered as major. The infestation by the major and promising insect and mite pests and their abundance, seasonal incidence their extent of damage of jhum and hill rice-cotton intercrop significantly varied with mean temperature, rainfall and humidity. Farmer's practices of Jhumian people treatment were less effective to suppress the insect pests predominant on hill districts. The rate of infestation, decreasing invasion over untreated control, yields, monsoon season, accessibility at hills, their traditional practices on different crops in jhum and hill rice-cotton intercrop, chemical treatment T_3 (spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water at 25 days interval) was most effective and other chemical treatments also performed significant and recovering of yield than traditional practices and untreated control plots.

CHAPTER I

INTRODUCTION

Jhum cultivation is an age old farming practice for growing agricultural crops in the hill slope in the hill districts in Bangladesh (Bai 2006). The area covers vast forest land, wide range of hills and alluvial valley bottoms. Cultivable plain land is scarce in Chattogram hill tract (CHT) region. Land suitable for intensive field crop cultivation is less than 5% of the total area (Bai 2006). The traditional agricultural economy is based on the growing of paddy and other crops in the valley bottom land. The utilization of hill slopes by shifting cultivation locally known as jhum. However, due to rapid growth in local populations the environment in the Chittagong Hill Tracts is under pressure. Demographic and environmental conditions are changing. Due to scarcity of suitable land, the traditional slash and burn farming system, locally known as jhum cultivation, is becoming unsustainable. This, combined with other factors such as forest overexploitation, is the cause of increased land degradation, such as soil erosion, nutrient decline, and decreased biodiversity.

Nevertheless, in CHT slash-and-burn agriculture, a kind of swidden or shifting cultivation in hills has been recognized as subsistence food production system for tribal minorities, namely Chakma, Marma, Tripura, etc. for centuries, the tribal communities have been practicing Jhum cultivation (Chakma and Ando 2008). Jhum cultivation and forest are still central role player to the traditional societies as their primary sources of food, shelter, medicine and other products and services (Chakma and Ando 2008, Ahmed and Gabby 1996,). The intimate relationships between the tribal minority and the hill farming system have enriched their ethnobotanical knowledge through ages (Khisa 1997a 1997b). The CHT shares border with the Arakan and Chin states of Myanmar, and Tripura and Mizoram States of India and consists of three hill districts of Rangamati, Khagrachari and Bandarban and it covers an area of 13, 295 km^2, about 10% of the country (Chakma and Ando 2008). There are twelve tribal communities living in the region who are traditionally all Jhum cultivators, although some of them are also used to and still occasionally do engage in hunting, fishing, gathering and herding activities. The Chak, Khyang, Khumi and Moru who lives mostly on the ridge-tops, are still largely Jhum cultivators. The Chakma, Marma, Tangchangya and Tripura who live on the gentle slopes and river valleys engage in Jhum cultivation. Until the early 1960s, Jhum practice was not considered to be very detrimental to the hill ecology. Population growth along with rapid deforestation has reduced the fallow period from 10-20 years to 2-3 years. The present average of 2-3 years fallow period cycle is too short for the regeneration phase of the cultivation and to regain soil fertility. The cycle is exacerbated by poverty coupled with persistent food shortages. Jhum cultivation is their way to ensure food supply for the families. The factors that contribute to the farmers' impoverishment are also the causes of Jhum cultivation. They include population pressure due to both inward migration and unawareness of the family planning, poor access to credit and technical knowledge, low education, poor healthcare, and underdeveloped market for farmers' products. Although there is a substantial volume of literature on the hill farming systems in abroad (Sunderlin 1997, Agalawatte and Abeygunawardena 1993, Araki 1993 and Goswami 1980) for the Sri Lankan; Zambia; India; Indonesia, respectively however, research on indigenous farming systems in Bangladesh has been strikingly limited (Chakma and Ando 2008, Hassan and Muzumder 1995, Hossain *et al*. 1985, Ishaq 1971).

Jhum cultivator produce almost everything whatever they need. Large numbers of cereals, vegetable, pulse, oilseed, spices, fruits and fiber crop were found to grow in the jhum fields and rice was always the main crop. It was noticed that about 30 crops, were grown in jhum chash (Kazal and Tapan 2013, Chakma and Ando 2008). Cultivators use many traditional varieties for each of the above mentioned crops. In the past 15 to 20 crops used to be grown together, which used to supply almost all the necessities of food and fiber. At present 5 to 8 crops were usually grown in a jhum field.

Rice and cotton are important crops for the tribal people of three hill districts. Clothes are mostly made of cotton, wool imported from Myanmar and silk cotton which is a rarity in most of Bangladesh. Cotton is spun and woven by hand in CHT by the tribal people. To promote local textile there now is a Bangladesh Small Cottage Industry Corporation (BSCIC) center in Bandarban together with a wonderful sales centre. BSCIC has also introduced mechanical spinning and weaving here. Hill cotton is a long duration crop and generally farmers grow cotton in jhum system. They cultivate cotton with other crops like rice, maize, sweet gourd, marpha, chenal, cucumber, ribbed gourd, white gourd, sesame, turmeric, cowpea, chili (bindu marach), taro, ginger, okra, brinjal and yard long bean, ufra sheem, bitter gourd, and country bean etc. at a time in hill slopes (Kazal and Tapan 2013, Farid and Hossain 1988). The important strategies to increase the domestic production from the limited land resource could be development of high intensity cropping system including intercropping. However intercropping *i.e*., growing two or more crops simultaneously in the same field during the growing season (Ofori and Stem 1987) has been proved to be an important production system in the tropical and sub-tropical region (Myaka 1996) and continue to be an important practice in the developing nations (Sullivan 2003). Total crop productivity and net return per unit area as well as land equivalent ratio are higher in intercropping system as compared to that of mono crop production (Saeed *et al.* 1999, Mohammad *et al.* 1991, Rao 1991). Cotton is a long duration but initially slow growing crop in a single or paired row keeping enough space in between that can be utilized by growing intercrops for 2-3 months after sowing (Singh *et al.* 2009, Musande *et al.* 1981), with an advantage of additional income per unit area. Intercropping of rice in between cotton rows has been reported to be highly productive and profitable (Patil *et al.* 1996, Dhoble *et al.* 1990, Farid and Hossain 1988, and Birajdar *et al.*1987). Several insect pests cause heavy yield loss in jhum and rice-cotton intercropping system. Farmers often apply traditional management options to solve the problem. Information on the status of the environment is required for the formulation of alternative strategies for sustainable management. The pressures on the environment and the causative factors and processes must be analyzed. New methods must be developed, applied, and tested for sustainable management of the natural resources (Miah and Islam 2007, Mantel and Khan 2006).

However, in a complex cropping systems application of traditional techniques often are not sufficient to solve pest problems effectively. Abiotic factors like temperature, relative humidity, it's extent and distribution, moisture evaporation from hill slope, sun shine hour with intensity, influenced the infestation and stabilization of various insect and mite pests in jhum and intercrop crops at hill districts of CHT. Jhum cultivation season (May to November) in Bangladesh hill region when maximum rainfall and high temperature prevailing during the jhum crops were at optimum growth stage i.e. July to September. The prevalence of low temperatures may be caused for lengthening the life cycle of some notorious insect pests, while at elevated temperatures those menacing insect pests complete their life cycle at a comparatively shorter duration. The overlapping generation of those menacing insect pests caused devastation to jhum and hill intercrops. Furthermore, some jhum fields are far distant from the owner habitation (village/Para), thus very difficult to monitor frequently the insect pest's incidence as well as their management for better yield. Little is known about information regarding insect pests' infestation, seasonal incidence, extent of damage in complex cropping system and management of major and promising insect pests infesting jhum and intercropping field crops in the selected area of CHT in Bangladesh. Therefore, there is a need to develop pest management options for sustainable production in diversified cropping system of hill districts of Bangladesh (John 2008). Application of modern technology for insect pest management can reduce their attack and increase crop yield (John 2008, Miah and Islam 2007).

The different areas of three hill districts of CHT in Bangladesh have generally been identified as a disadvantaged region in terms of poverty, food insecurity, environmental vulnerability and limited livelihood opportunities. The stress environment of the hilly areas of the country received very little attention in the past. The increased pressure of growing population demand more food that brings attention to explore the possibilities of increasing the potential of the hilly lands for increased production of crops. Moreover, cultivable land area is decreasing day by day in the country. In this context, there is no other alternative but to address less fabourable and unfavourable environments for food security and to adapt the climatic variability. The overall strategy for seventh five year plan of Bangladesh is to accelerate the process of transformation from existing semi-subsistence farming to commercialization of agriculture (Quais *et al.* 2017). The strategy requires achieving productivity gains, diversification, value addition and agro-processing commensurate with national environment protection and climate change adaptation strategies. (GED, 2015). Under these circumstances, the present study will be undertaken in particular, to look at how farmers' perceptions about the advanced pest management options for sustainable production in diversified cropping system be improved.

Under the above scenario, the present study was undertaken with the following objectives:

- to identify the major and minor insect pests of jhum and rice-cotton intercropping system,
- to find out the pattern of infestation of major insect pests in the hill districts,
- to determine population dynamics of major insect pests in jhum and rice-cotton intercropping and,
- to develop pest management approaches for suppressing major insect pests of jhum and rice-cotton intercropping system.

CHAPTER II

REVIEW OF LITERATURE

Reviews of the updates of the research findings regarding the prevailing scenario of jhum practices in Bangladesh, shifting cultivation (SC) at hill region of different countries, insect pest complex of jhum and rice-cotton intercrop at hill, particularly major and promising insect pests their distribution, biology, seasonal abundance, infestation levels, nature of damage, yield loss and available management practice for their effective management are discussed under the following subheadings:

2. Jhum cultivation

2.1. Concept of jhum or shifting cultivation

Jhum or shifting cultivation is an indigenous farming system in the tropical and subtropical regions readily inaccessible zones. Shift farming has been often and highly practiced by indigenous communities in many centuries. It takes place and occurs in Amazon rainforest areas, West and Central Africa as well as Indonesia. The major concept of the system is to utilize a piece of land for few (one to four) years and leaving the land for 10 to 20 years (even longer) for fertility restoration through the natural process. It is the foundation of the economic structure of the ethnic community and is the principal source of livelihood. Jhum cultivation and forests are still central to the traditional societies as their primary source of food, shelter, medicine and other products and services. Farmers have developed a close bond with jhum cultivation, which they have been practicing on steep to very steep hill slopes since time immemorial. The choice of crops mainly depends on the food habit and requirements of the people and soil condition of the area (Kazal and Tapan 2013, Hossain 2011, Ahmed and Gaby 1996).

Hossain (2011) reported that in Bangladesh rice is the major component, where cucumber, marpha, cinar, cotton, beans, ladies finger (okra), chili (Bindu morich), hill sesame, maize, and flowers etc. also used to grow in jhum cultivation (Kazal and Tapan 2013).

Studies on jhum farming by Indian Council of Agricultural Research (ICAR) revealed that the input-output ratio was 1:1.28. Jhum cultivation in a mixture or alone is an un-remunerative enterprise with very low returns (Berthakur *et al.* 1983, Datta and Sharma 1979).

2.2 Jhum cultivation in Bangladesh

Several researchers reported that slashing of vegetation and subsequent burning in the dry season, followed by dibbling of seeds after the onset of rains (generally in April) are common in jhum cultivation system in the CHT. According to Kazal and Tapan 2013, Dasgupta *et al*. 2008 normally land is cleared of shrubs, herbs and undergrowth vegetation, leaving the trees intact and all crops are planted at the same time under zero-tillage condition. After the onset of rains, crop germination and establishment pick up fast and along with other weeds, the crop plants also grow vigorously. Jhum crops are harvested one by one as they ripe successively between July to December.

In Bangladesh, for last two decades, continuous jhum cultivation period in one place of land never exceeds more than two years and restoration cycles shorten to 3-4 years. Reasons for shortening of jhuming cycle have been reported by several scientists. As explained by Jha (1997) referring to Upadhyaya and Jha (1995) that jhuming, cycle is the time elapsed between leaving the first plot and returning to it. The cycle determined the ratio between the area under jhuming and the area under jhuming in a certain year. According to Sachianda 1989, Hossain 2011, the higher the density of population the shorter the jhum cycle. No major research focuses on the key issues of jhum farming in CHT.

Kazal and Tapan 2013 reported that the tribal people of CHT like dry fishes and vegetables in their everyday food. They also collect their foods from nearby forest such as bamboo shoots, tara, some spices. They prefer aromatic and sticky rice which are produced in jhum. In jhum they cultivate about 30-40 types of fruits, vegetables and spices. So as a whole jhum cultivation sometimes called food bank of the tribes. Round the year hill people collect their day foods from nearby jhum. Even jhum produces are sold to the weekly market.

Mukul *et al.* (2011) reported that mixed cropping is the dominant phenomena of jhum system Rice is the main crop in the jhum, but all rice varieties are locally adopted. In the past, about 15-20 non-rice crops used to be grown with rice in the jhum but the numbers of the crops subsequently come down to about 6-8. The jhum crops used to supply almost all the necessities of food and fiber of the Jhumias. Jhumi is considered to be the storage of Jhumia families and offers food security.

2.2.1 Benefits of jhum/ shifting cultivation

Watters 1971, mentioned that there are several variations in the practice in different parts of the world, in general, all forms of shifting cultivation follow five stages: site selection, cleaning, burning, cropping and fallowing. While Indonesian farmers mentioned five advantages of burning in shifting cultivation, these were, (a) burning creates space, (b) ash acts as a fertilizer, (c) burning improves soil structure enabling faster establishment of seedlings, (d) reduces weed and tree competition and (e) it reduces beneficial aspect of shifting cultivation that deserves to be exploited and the occurrence of pests and diseases (Ketterrings *et al*. 1999).

Lal *el al.* 1975 and Ahn 1974 testified about beneficial aspect of shifting cultivation that deserves to be exploited and incorporated in alternative and improved land use systems for the restoration of soil productivity that takes place during the fallow period through physical and biological processes of rain wash, litter fall, root decomposition associated with re-vegetating the area. They also described that benefits of slash-and-burning is improving soil fertility by immediate release of concluded minorals nutrients for crop use seem to be short-lived due to its degenerate effective soil physical properties.

The addition of ash in the soil by burning causes important changes in soil chemical properties and organic matter content (Jha *et al.* 1979). While Sanchez and Salinas (1981) described that in general, exchangeable bases and available phosphorus increase slightly after burning; P^H values also increase, but usually only temporary. Organic matter content (OM) is also expected to increase by burning, mainly because of the unburned vegetation left behind.

Ahn, 1974 and Lal *el al.* 1975 found that cleaning and burning the vegetation leads to a disruption of this closed nutrient cycle. During burning the temperature increases, and afterward, more solar radiation is received on the bare soil surface resulting in higher soil and air temperatures. This change in the temperature regime ceases resultant changes in the biological activity in the soil. This phenomenon of improvement of soil fertility during the fallow period has been demonstrated by numerous studies (Mishra and Ramakrishnan 1983, Koopmans and Andriesse 1982, Aweto 1981, Nye and Greenland 1960).

2.2.2 Disadvantages of jhum Cultivation

On the other hand, shifting cultivation is considered as the major factor for deforestration, soil degradation and nutrient depletion in the mountainous regions of the world (Kazal and Tapan 2013, Rahman *el al.* 2011, Nair 1993, World Bank 1991). The threats of soil degradation and soil erosion due to jhuming can affect the vitality of native vegetation due to loss of necessary nutrients and soil features needed for their natural survival.

Ramakrisnan 1992 reported that Garo hills landscape, being a wildlife hub is being negatively affected by unsustainable jhuming. The overall reduction in the forest, mainly due to jhuming can severely affect the habitat several of the endangered fauna like the Asian Elephant and Hoolook gibbon.

Washing of fertile topsoil with exposure of rocks due to the transportation of soil was result of Jhuming had been reported by Goswami 1968, Chandralekh 1992 and Jha 1997 explaining the impact of Jhuming that it has seriously affected large areas of Indian forest.

Berthakur *et al.* 1983 reported that resource degradation, low productivity, tendency to encourage large family size and little or practically no scope for application of improved agricultural production technology, shorting of Jhuming cycle due to population pressures etc. are drawback of Jhum system. Similar views expressed by Jodha (1991) and Shestra (1992).

The main problem of jhum cultivation system is poor productivity. The seeds are not of improved variety and their yield potentiality is not high. More over the farmers do not follow different improve management practice like weeding, fertilizing, pest management etc. For this the jhum farmers don’t get good harvest. The scarcity of land is another problem of jhum. During jhum hill preparation, burning destroys all types of living organisms and herb & shrubs. So it disturbs the biodiversity. If the farmers use spade for cultivation then it may cause soil erosion during rainy season (Kazal and Tapan 2013).

2.2.3 Jhum cropping pattern and intensity

The overall crop diversity index (CDI) for the region was 0.96. The highest CDI was in Rowangchari (0.99) of Bandarban followed by Lama (0.96) of Bandarban and the lowest in Belaichhari (0.82) of Rangamati. The single, double and triple cropped area in the region was 33.3%, 32.1% and 3.1% respectively of the net cropped area. The average cropping intensity (CI) of the Chittagong Hill Tracts was 139%, the lowest in Ruma (100%) of Bandarban and the highest in Manikchari and Panchari (164%) of Khagrachari (Quais *et al.* 2017). Similar views overe expressed by Kazal and Tapan Kumar Paul 2013.

Swapan *et al.* (2010) mentioned in their finding that there is a great yield difference among jhum rice, plain land and riverside planted rice. This variation is due to the cultivation of crops in jhum land in a mixed pattern with subsistence level of management, whereas plain land rice and riverside land get the maximum management. Although the jhum farmers are intended to grow plain land rice more but they cannot, due to severe land shortage with some other edaphic problems. They are also trying to cope with this sort of problems. In the jhum land, crops are grown in a mixed way and the number of crops are more than that of plain land (where only mono rice crop is grown) it has been found that the total gross profit for one hectare of jhum rice in one year is about 36310 Tk., which is rather low in comparison with plain land rice (gross profit is about 72040 Tk. in one hectare of land in one year).

2.2.4 The traditional jhum cultivation

The traditional jhum cultivation is based on rain fed condition is the most common practice in the CHT region. The main crops generally grown in jhum include rice, sesame, chili, ginger, turmeric, cucurbitaceous (sweet gourd, marpha, chinal, bitter gourd etc.), maize, banana, aroids, cotton, okra etc. Along with jhum cultivation, the upland area is also cultivated for other single crop like turmeric, zinger and aroids or covered with fruit garden, forest trees in rain fed condition (Kazal and Tapan 2013).

2.2.4.1 Importance of fallowing in shifting cultivation

Weed suppression and buildup of ecosystem fertility are the two major reasons for fallowing. The fallowing phase is essential to help restore soil fertility lost during the preceding cropping phase (Liang *et al*. 2009). Many studies have demonstrated that weeds become more problematic when the fallow is short (De Rouw 1995, Dingkuhn *et al.* 1999). When the fallow period goes below 3-4 years, soil fertility is not renewed, and erosion and weed competition increase dramatically (Van Keer 2003). Yield levels in shifting cultivation are influenced by a wide range of biophysical, socioeconomic, and cultural factors and it is difficult to isolate fallow length as a single determining factor (Hossain 2011).

2.2.5 Intercrop cultivation

Intercrops or more diverse systems tend to have high density of predators and parasitoids than monocrops, and hence lower insect infestation. Intercropping studies by Beets (1981), Wahua and Miller (1978) and showed that intercropping reduced pests' incidence.

Epidi *et al.* (2008) described that intercropping rice with cowpea increases green stink bug incidence over rice monocrops for the wet and dry season cultivations. On the other hand, intercropping rice with groundnut at low and medium populations of groundnut results in lower green stink bug and stem borer infestation. It is therefore recommended that for reduced infestation by these pests and optimum rice production, rice should be intercropped with groundnut at a population of 100,000-200,000 plants/ha.

2.3 Insect pest complex of jhum and intercrop

2.3.1 Rice field common pest

Chanu *et al*. (2010) reported that blast and brown leaf spot are the most common foliar fungal diseases of rice whereas brown plant hopper, white backed plant hopper, case worm gall midge, stem borer, *etc.* are the common insect pests. Similar views have been expressed by different authors working in the areas of traditional knowledge for the sustainable management of crops in traditional farming systems (Thurston 2019, Chhetry and Belbahri 2009).

Nasiruddin and Roy (2012) reported 35 species belonging to 13 families and 30 genera and they were collected and identified. Four economically important orders of insects were Hemiptera, Orthoptera, Lepidoptera and Coleoptera. Insect pests were abundant during seedling growth stage trailed by transplanting and flowering. Insect orders showed an increasing trend of population as Hemiptera being highest followed by Orthoptera, Lepidoptera and Coleoptera.

Different experiment on different year carried out by BRRI and stated almost 20 insects are considered as rice pests of economic importance that include stem borers, gall midge, defoliators and vectors like leafhoppers and plant hoppers that cause direct damages and transmit various diseases (BRRI 2007-2009).

Insects are a major constraint of rice production. The brown plant hopper (*Nilaparvata lugens*), rice stem borer (*Sciropophaga* spp.), green leaf hopper (*Nephotettix* spp.), white-backed plant hopper (*Sogatella furcifera*), rice gall midge (*Orseolia oryzae*), rice hispa (*Dicladispa armigera*), and rice leaf folder (*Cnaphalocrocis medinalis*) are common insect pests of rice in Bangladesh (Alam 2013, Fatema *et a*l. 1999, Kamal *et al*. 1993 and Alam, 1981). They also stated that most of rice plant parts are exposed to pest attack from period of sowing till harvest. Insect damage plant parts by chewing plant tissues, boring into stems or sucking fluid saps from stem and grains. Damages caused by insects disturb physiology of plants and result in to lower crop yield

2.3.2 Insect and mite pests of marpha (hill squash)

Squash is an economically important plant cultivated throughout the world as vegetable crops and for medicinal products (Caili *et al*. 2006). Its importance as an economical and medicinal plant is becoming increasingly apparent. It is rich in nutrients and bioactive compounds, such as phenolic, flavonoids, vitamins, amino acids, high carotenoids content with values of 171.9 to µg/10g, carbohydrates (66%), proteins (3%), crude fibre (11.46%) and minorals (especially potassium), and it is high in energy content (about 80Kcal/100g of fresh squash) (Tamer *et al*. 2010).

The tephritid fruit flies of genus (*Bactrocera*), with more than 500 species currently described constitutes important pests of reproductive stages of a number of fruits and vegetable crops in Asian countries (Kumar *et al*. 2011). They have great economic importance because they are considered the key pests that most adversely affect the production and marketing of vegetables and fruits around the world (Uchôa 2012).

Ronald (2003) reviewed five species of fruit fly in Bangladesh e.g., *Bactrocera brevistylus* (melon fruit fly), *Dacus caudatus* (fruit fly), *D. cucurbitae* (melon fly), *D. tau* (mango fruit fly) and *D. zonatus* (zonata fruit fly) caused significant damage of respected fruits in different season. (Mandal 2015, Vijaysegaran 1987) also support the above finding and mentioned two of the world's most damaging 15 tephritids *Bactrocera (Dacus) dorsalis* and *Bactrocera (Dacus) cucurbitae*, are widely distributed in Malaysia and South East Asian countries.

Kumar *et al*. (2011) reported that, the damage starts when the female fruit fly punctures the fruit with its long and sharp ovipositor. The fruit skin is breached, and bacteria enter and the fruit starts to decay. The larvae that hatch from the eggs feed on the decaying fruit tissue, and on the yeasts and bacteria that multiply in it. Fruit fly females carry bacteria with them that they inject into the fruit at oviposition so that the fruit decays faster (making it more nutritious for the larvae).

2.3.3 Insect and mite Pests of chili

Chili, *Capsicum annum* L. is one of the important condiments having immense commercial dietary and therapeutic values. Chili plant is infested by numerous insect pests that attack chilies at its various growth stages. It is often infested by a group of either sucking or boring pests. Severe damage normally occurs when a large number of pests feed on the plants. The major pests of chili are the sap sucking insects which include the thrips, aphids and whiteflies and the boring insects, mainly the fruit borers. Mites which are non-insects also pose major problem. The most obvious pest damage symptoms are on the leaves and fruits. Leaf curls and rotting of fruits are common and serious at a time (Sorensen 2005, Lingappa *et al.* 2002 and Thamsborg 2002)

Wills (2011) described nearly 25 insects attacking chili leaves and fruits, of which thrips, *Scirtothrips dorsalis* Hood (Thripidae: Thysanoptera) is considered as the most serious and important pest and the yield loss of green chili due to thrips ranged from 60.5 to 74.3 %. Similar observation was reported by Sorensen (2005) and mentioned several 35 species of insect and mite infesting chili which includes thrips, aphids, whiteflies, fruit borers, cutworms, plant bug, mites and other minor pests. However, Thamsborg (2002) stated that success is little in controlling these insect pests.

Moanaro and Jaipal (2018), Bugti *et al*. (2014), weather parameters as independent variable and thrips, mites and whiteflies population fluctuation as dependent variable they obtained 42, 65 and 47 percent population variability, respectively. So, environmental varables played significant role in distribution and abundance of mites population on capsicum and chili.

Bugti *et al*. (2014) also found from their experiment that a total 7 species i.e., jassid, thrip, whitefly, aphid, mealy bug, fruit borer and termite were found infesting crop at its varius development stages, when the pests arrived on the crop the predators were also appeared on pests of crop. The highest pest population of whitefly was recorded followed by jassid, thrip, aphid, mealy bug and fruit borer. However the mealy bug infestation was lower than other insect pest throughout the seasons. Vos and Frinking (1998) who reported that *Helicorverpa armigera*, jassid, thrips, armyworm and spodoptera were infesting the *Capsicum* sp. Abdulahi (1992) who recorded attack of termites that caused damage by cutting the bark of the stem/roots at ground level. The results also agree with Sunitha (2007) who carried out investigations on survey of insect pests of capsicum, preparation of checklist of insect pests which occur at different crop growth.

2.3.4 Insect and mite pests of sesame

This crop is attacked by 29 species of insect pests in different stages of its plant growth (Egonyu *et al*. 2005). In India, sesame crop is attacked by 30 species of pests, of which shoot webber and capsule borer both are an important pest causing 10-60% yield loss (Ahirwar *et al*. 2010). These pest caused 10 to 70% infestation of leaves, 34 to 62% of flower buds / flowers and 10 to 44% infestation of pods resulting 0 to even 72% yield losses (Singh 2003).

Egonyu *et al*. 2005 reported sesame is attacked by numerous pests and diseases that reduce its yield and lower the quality of the seed. Thirty eight insect pest species have been found to infest sesame in Uganda, of which the sesame webworm (*Antigastra catalaunalis* Dup.) is considered most important, with 62% occurrences in northern Uganda.

2.3.5 Insect and mite pests of cotton and okra

In Bangladesh, its sub-tropical climate results in severe pest infestation and the crop is subject to be damaged by 162 species of insects those are generally classified into sucking and chewing pests **(**Amin *et al*. 2008**).**

It is found that jassid, aphid, white fly and thrips are the major sucking pests of cotton and okra (Bohlen, 1984). Amjad *et al*. (2009) observed the sucking insect pest abundance on five cotton cultivars and found aphid and jassid infestation on the cotton varieties in the middle of September and continued throughout the season. Selvaraj and Ramesh (2012) and Shivanna *et al*. (2011) found the abundance of aphid on cotton throughout the season except July, August and September when the rainfall was very high.

According to Amin *et al*. (2017), in the varieties CB1, CB3, CB5, CB8 and CB12, mean abundance of aphid and jassid ranged from 4.3 to 6.4 and 7.3 to 13.1 leaf^{-1}, respectively and the results differed significantly. CB12 inferted significantly by higher number of aphid and jassid population compared to other varieties. Jassid population had significant negative correlation with maximum and minimum temperatures, relative humidity and rainfall. The weather parameters combine contributed significant effect on the population (Amin *et al*. 2017).

Environmental factors like relative humidity, temperature and precipitation play a key role in multiplication and distribution of insect pests and also affect agricultural production. Climatic and weather changes not only affect the status of insect pests but also affect their population dynamics, distribution, abundance, intensity and feeding behavior (Ayres and Schneider 2009).

A study done by Mahmood et al. (1990) in Pakistan showed that the weather parameters together were responsible for 73.0% population fluctuation of aphid on okra plants. On the contrary, statistically negative significant correlation was found between aphid population with relative humidity and temperature. So, it can be concluded that the population of aphid was increased with decreasing temperature and vice versa (Sain *et al*. 2017).

Allen *et al*. (2018) conducted an experiment at USA and result revealed that importance of some of cotton pests is dependent of the cotton-growing region and impacted by local production practices. Thrips (Thysanoptera: Thripidae) are the most prevalent early-season insect group in cotton across the United States and the primary target of initial insect control. Other targeted insects include the black cutworm, *Agrotis ipsilon* (Hufnagel) (Lepidoptera: Noctuidae), aphids (predominantly *Aphis gossypii* Glover) (Hemiptera: Aphididae), plant bugs (Hemiptera: Miridae), and wireworms (Coleoptera: Elateridae).

2.3.6 Major insect pests of yard long bean and/or alike crops

Legume pod borer population build-up is related to cumulative rainfall and the number of rainy days between crop emergences to flowering (Sharma 1998). The insect is multi voltine having at least two overlapping generations are in most places of its distribution. Being a multivoltine insect with polyphagous nature of food habits, and with preference for some particular parts of a particular host plant legume pod borer is likely to differ in its seasonal distribution spatially even within a host plant and temporally within the growing season of a particular host plant. Again, the weather pattern varies across continents, and therefore, the seasonal distribution of the insect is likely to vary regionally as well.

Uddin *et al*. (2014) reported that the Insect pests of yard long bean Hairy caterpillar (*Spilosoma obliqua*.), leaf beetle (unidentified), hooded hopper (*Leptocentrus taurus*), thrips (*Megalurothrips* spp.), leaf minors (unidentified), red mite (T*etranychus* spp.), green sting bug (*N. viridula* L.), semilooper (Diachrysia spp.), aphid (Aphis craccivora), and pod borer (*Euchrysops cnejus*) were the common insect pests of farmer's field in surveyed areas while the population incidence was much higher in case of aphid and pod borer.

2.4 Management

Sufficient food production for a growing human population has become an issue of global concern. Almost all of the world's fertile land is currently in use and arable land areas cannot be expanded significantly. The global challenge is to secure high and quality yields and to make agricultural production environmentally compatible. Insects have been hugely successful in terms of both species richness and abundance. Insects have been predominantly perceived as competitors in the race for survival. Herbivorous insects damage 18% of world agricultural production. Despite this damage less than 0.5 percentage of the total number of the known insect species are considered pests (Jankielsohn 2018). To ensure stable crop yields we need to change the management strategies of agroecosystems. We need to manage these systems in such a way that insects performing valuable ecosystem ser-vices are also incorporated into the system. This will ensure stable, resilient and sustainable systems in a constantly changing environment and will go a long way to ensure future food security.

2.4.1 Cultural control

Among the environmental factors, rainfall appeared to be one of the important key factors; the distribution of rainfall over time is more critical than the infestation of different insect pest's populations. Thus, the adjustment of planting dates in such a way that the crop receives rainfall for a considerable period from flowering to harvest has been suggested as a component of a pest management system that is structured in an Integrated Pest Management (IPM) set-up. In Bangladesh, rain is usually frequent in kharif season, and yard long bean which is grown in summer, can be used for exploiting the advantage of rainfall distribution in summer. Again, pod borer populations tend to build up over the season (Ekesi *et al*. 1996), the pod borer infestation increases on the late sown crop (Alghali 1993). In such a case, yield may be affected, as is the case with cowpea, grain yield decreases in late planted crops (Euzeh and Taylor 1984), in such a case early planting might help reduce legume pod borer infestation.

Cropping system has profound effect on pod borer infestation. It has been noted that simultaneous planting of Maize and cowpea increases borer infestation in cowpea (Euzeh and Taylor 1984), whereas showing cowpea, 12 weeks after sowing of maize reduces the pod borer damage. As a cultural practice of controlling for pod borer infestation, intercropping has been successfully used. It has been reported that pod borer damage in a monocorp is greater than the maize-cowpea-sorghum crop grown as intercrops (Fisher *et al*. 1987, Amoaka-Atta *et al*. 1983, Amoaka-Atta and Omolo1982).

2.4.2 Effect of mechanical control

Anonymous (2000) reported that benefit cost ratio among different treatments for the management of *Helicoverpa armigera* in pigeon pea, mechanical control (shaking) showed the highest benefit cost ratio (1:7.1) and neem oil provided 1:4.6. Whereas Hossain *et al*. (2003) found that mechanical control of infested plant part of bitter gourd reduced 42.87% attack of an Epilachna beetle over control.

Maleque *et al*. (1999) reported that the ladybird beetles and spiders were seriously affected in the field where Cypermethrin was applied at weekly intervals compared with fields where mechanical control and few sprays were applied and control fields. Hand picking of infested shoots and fruits was used as a component of IPM and it was reduced the damaged fruits of brinjal per plot compared to greater in plots with single picking (Verma 1986).

2.4.3 Chemical control

Dutta *et al*. (2004) reported that two sprays of Zeta-cyphermethrin (Fury 2.5 EC) appeared to be the best method and offering the lowest pest incidence (14.21%) of pod borer and highest BCR (10.84) in yard long bean (*Vigna ungulicata* spp. *Sesquipedalis* (L.) Verdc).

Uddin (1990) reported that besides pest control, highest yield of cowpea (*Vigna unguiculata*) was obtained from granular carbofuran treatment in rows. He also found that soil treated insecticides such as carbofuran and Thimet were very effective Chemicals to reduce the incidence of bean flies on cowpea.

Efficiency of some synthetic and bio-pesticides against pod borer, (*Helicoverpa armigera*) (Hubner) damage in chickpea was studied at the Regional Agricultural Research Station, Ishurdi, Pabna, Bangladesh during rabi season of 2004 to 2005(Hossain 2007) synthetic and biopesticides reduced pod borer damage considerably. Significantly the lowest damage was observed in Cypermethrin (5.75%) and HNPV (5.86%) sprayed plots followed by carbaryl (6.05 %) and dimetholet (7.92%) treated plots. The bio-control agent, HNPV, showed equally the best performance like synthetic insecticides and also showed higher efficacy then neem based insecticides like nimbicidine (Azadiractin 0.03% EC). Pod damage reduction by synthetic insecticides and bio-pesticides over untreated control ranged from 24.98 to 64.84%. It range from 50.53 to 64.08% in case of synthetic insecticides and 24.98 to 63.40% in case of bio-pesticides (Hossain 2007).

Yield loss due to insect pests of rice has been estimated at about 30 - 40% (Heinrichs *et al*. 1979). Control of these insect pests has been achieved with the use of insecticides.

2.4.4 Integrated management

Adipala *et al*. (2010) reported that in Uganda diverse cowpea pest complex dictated that a single control strategy was unlikely to produce satisfactory control.

Mensah (1997) found that intercropping three rows of copy alternatively with two or three rows of sorghum and spraying gave a yield advantage of 58 to 69% and was, therefore, the most productive method to be adopted by subsistence farmers of Northern Guinea Savannah ecological zone of Nigeria.

According to Sharma (1998), Legume pod borer, *Maruca* (*testulalis*) *virata* (Geyer) is one of the major constraints in increasing the production and productivity of grain legumes in the tropics. He reported that multi-tactics which were incorporated in the IPM package, specially screening techniques, chemical, cultural, biological and biotechnological methods were effective for controlling pod borer in diverse agro-ecosystems.

2.5 Population ecology

2.5.1 Population dynamics

It was studied that population dynamics of pests was related with kind of vegetation and growth stages of rice crops (khan 2013).

Predicting the occurrence of insects with a high accuracy requires the estimation of insect development time and the variation among individuals for each life stage and species under different environmental conditions such as fluctuating temperature, variation of relative humidity, different body sizes and stages of the insects, levels of crowding, and food supply (Fuji *et al*. 2018).

CHAPTER III

MATERIALS AND METHODS

The present investigation, "Development of pest management approaches for jhum and rice-cotton intercropping system in the hill tracts of Bangladesh" was conducted at four separate experiments during March 2014 to February 2016 at jhum fields in different hills of Bandarban, Rangamati and Khagrachari. The data obtained for different characters were statistically analyzed to find out the significance of effects/impacts of different insect pests management practices and insect pest diversity of jhum and rice-cotton intercropping fields. Insect pests and infested plant samples were analyzed in the Laboratory of Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur and Sher-e-Bangla Agricultural University, Dhaka. The following four field experiments were carried out at different hills of Bandarban, Rangamati and Khagrachari:

I. Survey on insect pests of existing cropping system and farmer's practices for their management in hill tracts of Bangladesh.
II. Identification of common insect pests found in jhum and rice-cotton intercropping system.
III. Population dynamics and extent of damage of major insect pests found in jhum and rice-cotton intercropping system.
IV. To develop pest management approaches for jhum and rice-cotton intercropping system.

3.1 Survey on insect pests of existing cropping system and farmer's practices for their management in hill tracts of Bangladesh

The study was carried out in six Upazila of three hill districts of Bangladesh selected for survey. Randomly selected total 150 farmers, 50 farmers per district from three hill districts. They were interviewed through structured questionnaire (Appendix 8.4) to collect relevant data and 125 plots were visited (Table 3.1.1). The Farmer's view/opinion collected were related to basic information such as age, education, jhum farming experience, training on pest management and other, farmer's information on problems of jhum cultivation, major pests of jhum cultivation, source of pest management information, extent of damage and their traditional pest management system through structured questionnaire to collect relevant data during March 2014 to January 2015. Such field data collection activities were assisted by the Scientific Assistance (SA) of Krishi Gobesona Foundation (KGF). The basic demographic data of each of the selected farmers were collected by administering a simple pre-designed and pre-tested checklist.

Table 3.1.1 Selected jhum cultivation locations for survey and their AEZ

Sl. No.	District	Upazila	Total number of farmers	Name and AEZ
1.	Khagrachari	Khagrachari Sadar	20	Northern and Estern Hills AEZ: 29
		Matiranga	20	
		Guimara	10	
2.	Bandarban	Bandarban Sadar	30	
		Rwangchari	20	
3.	Rangamati	Kawkhali	50	

3.1.2 Analysis

The mean values of different parameters were calculated from the same farmers practices (FPs) and chemical (s) or group of chemicals used by the farmers and all the characters were evaluated, analysis of variance (ANOVA) was performed by the 'F' (variance ratio) test using MSTAT-C program. The pre-tested structured questionnaire has been given in the (Appendix 8.4)

3.2 Identification of common insect pests found in jhum and rice-cotton intercropping system

The present investigation was carried out during jhum season April 2014 to January 2015 at different locations of Khagrachari, Rangamati and Bandarban districts. Field data were collected from farmer's field of jhum and rice-cotton intercropping of different hill jhum farmers' fields covering; how many insect pests were associated with it and in what sequence they were appeared on the crop, the insect pest succession was formulated. The details of crop field are as follow.

3.2.1 Method of observations

Field scouting were done at 15 days interval to identify the major as well as minor pest pests. Patterns of infestation and extent of damage caused by the pest will be determined at field level. However, study also include four short field visits of two or three days, for example, during the harvesting time of some jhum products. Products were harvested at different times of the year. For example, rice, sweet gourd, ribbed gourd, marpha, cinar, beans, chili, okra, sesame, maize, cotton and other crops were harvested from August through November. The infestation of different crops was recorded by counting healthy and damaged plant parts from five selected plants from each experimental unit. The population was expressed in number plant^{-1}. Similarly, after fruit formation, the numbers of healthy and damaged fruits were counted at each observation. Then percentage values were calculated.

3.2.2 Experimental site, climate and duration

The study was conducted in the Seingulipara, Guimara upazila, Khagrarachari district; Shapchari, Rangamati district; Tigerpara, Bandarban Sadar of the CHT (Chattogram Hill Tracts) during April 2014 January 2015. The experimental sites are situated in subtropical climate zone, characterized by heavy rainfall during the month of April to October and scanty rainfall during the rest of the year. Hill slopes are very steep. The predominant general soil types of the experiment sites are brown hill soils (FAO/UNDP, 1988). Soil texture varies from sandy loam to sandy clay-loam. Hill soils are mainly yellowish brown to reddish brown-loam and grade into broken shale or sandstone at a variable depth, usually between 0.25 to 1.0 m. Organic matter (OM) content and general fertility are low. The meteorological data including maximum (Max.) and minimum (Min.) mean monthly temperature (°C), total rainfall (mm), and relative humidity (RH) during the crop growing period were recorded from the adjoining meteorological station of the Rangamati, from Ramgar Hill Research Station (BARI), Khagrachari and from SRDI regional station, Bandarban districts (Appendices 8.1, 8.2 and 8.3).

3.3 Population dynamics and extent of damage of major insect pests found in jhum and rice-cotton intercropping system

The experiment was conducted in the farmer's field at hill districts of Bandarban, Rangamati and Khagrachari from 2015 to 2016. The main target of the experiment was to study the dynamics of insect pests for the hilly regions of Bangladesh and to determine the extent of damage caused by the different insect mite pests of jhum and cotton-rice intercrop.

3.3.1 Method of observations

Field scouting were done at 15 days interval to observe the seasonal infestation of major as well as minor insect pests. Patterns of infestation and extent of damage caused by the pest were determined at field level. Field data were collected from farmer's field of jhum and rice-cotton intercropping during April 2015 to January 2016 at different locations of Khagrachari, Rangamati and Bandarban districts under the field conditions. These observations were made to assess the pest occurrence and population fluctuations during the cropping seasons. For this purpose, (5-10) plants were randomly selected from each experimental plot of 3m×4m size, replicated four times, to determine insect pests infestation and population abundance observed through nature of damage of each insect, infested plant parts were counted and recorded separately for each insect of each experiment. The meteorological data of temperature, relative humidity and rainfall during jhum cropping period. The correlation co-efficient between different weather parameters *viz.*, maximum and minimum temperature, rainfall, relative humidity and mean population counts of different insect and mite pests were counted for finding the effect of weather on seasonal incidence of each insect pest.

3.4 Development of pest management approaches for jhum and rice-cotton intercropping system in hill districts of Bangladesh

Field data were collected from farmer's field of jhum and rice-cotton intercropping system in two consecutive years during April 2015 to January 2016 and during April 2016 to January 2017 at different locations of Khagrachari, Rangamati and Bandarban districts under the field conditions to evaluate the efficiency of some selected insecticides, and mechanical destruction of infested plant parts with larvae by hand picking for managing major insect pests of both jhum and rice-cotton intercropping system. The meteorological data including maximum and minimum mean monthly temperature (°C), total rainfall (mm), and relative humidity (RH) during the crop growing period were recorded from the adjoining meteorological station of the Rangamati, from Ramgar Hill Research Station (BARI), Khagrachari and from SRDI regional station, Bandarban districts.

3.4.1 Method of observations

Experiments on jhum and rice-cotton intercropping were conducted separately in farmer's field of Bandarban, Rangamati and Khagrachari districts during 2015 and 2016. In Rangamati, the experiment was laid out in the field of Hemokumar Chakma at Sukurchari. In Bandarban it was carried out in the field of Kaisong Morong at Mrolong Para. Whereas at Khagrachari, the experiments was established in the field of Ukhai Marma, Shingulipara, Borkila, in Guimara upazila. Farmers were randomly selected with the help of Scientific Officers (SO) and Scientific Assistants (SA).

For jhum experiments during crops were grown following the standard methods used by the jhum farmers and the experiments were laid out in Randomized Complete Block Design (RCBD) with four replications. The distance between block to block and that of the plot to plot was 1.0 m each. There were five treatments namely, **T_1**= Farmers practice, **T_2**= Spraying Actara 25WG @ 0.5 g Liter^{-1} water at 25 days interval, **T_3**= Spraying Voliam Flexi 300SC @ 0.5ml Liter^{-1} water at 25 days interval **T_4**= IPM (Nappy trap+ Hand Weeding+ Spraying Voliam Flexi 300SC @ 0.5 ml Liter^{-1} water applied when necessary) and **T_5**= Untreated control**.** Whereas during 2016 following similar standard methods the jhum farmer's experiments were laid out in Randomized Complete Block Design (RCBD) with four replications. The distance between block to block and that of the plot to plot was 1.0 m each. Effect of different treatments on insect pests of jhum and intercrop experiments to suppress their infestation during 2015 some new treatments were added to evaluate the efficacy during 2016. The selected six treatments were namely, **T_1**= Spraying Marshal 20EC @ 2.0 ml Liter^{-1}

water at 25 days interval, **T_2**= Spraying Actara 25WG @ 0.5 g Liter^{-1} water at 25 days interval, **T_3**= Spraying Voliam Flexi 300SC @ 0.5 ml Liter^{-1} water at 25 days interval, **T_4**= IPM (Nappy trap+ Hand Weeding+ Spraying Voliam Flexi 300SC @ 0.5 ml Liter^{-1} water apply when necessary) and **T_5**= Ripcord 10EC @ 1.0 ml Liter^{-1} water at 25 days interval and **T_6**= Untreated control**.** Both the year each treatment was started to apply 30 days after sowing (DAS).

Data were collected from different crops grown in jhum on the following parameters-

- Number of insect pests infested plants 10 plants^{-1}
- Number of healthy plants 10 plants^{-1}
- Number of insect leaves^{-1} stems^{-1} flowers^{-1} bolls^{-1} cobs^{-1} fruits^{-1}etc.
- Weather data**-** temperature, relative humidity, and rainfall data.
- Total yield
- Healthy yield
- Yield increase due to treatment applications

For rice-cotton intercrops experiments were grown in farmer's field using two rows of rice and one row cotton. Experiments were laid out in Randomized Complete Block Design (RCBD) with four replications. The distance between block to block and that of the plot to plot was 1.0 m each.

For rice-cotton experiments crops were grown in farmer's field using two rows of rice and one row of cotton. Experiments were laid out in Randomized Complete Block Design (RCBD) with four replications. The distance between block to block and that of the plot to plot was 1.0 m each. There were five treatments namely, **T_1**= Farmers practice, **T_2**= Spraying Actara 25 WG @ 0.5 g Liter^{-1} water at 25 days interval, **T_3**= Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water at 25 days interval **T_4**= IPM (Nappy trap+ Hand Weeding+ Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water apply when necessary) and **T_5**= Untreated control**.**

Again for rice-cotton intercrop experiments similar six treatments were selected to evaluate their performance and those were namely, **T_1**= Spraying Marshal 20 EC @ 2 ml Liter^{-1} water at 25 days interval, **T_2**= Spraying Actara 25 WG @ 0.5 g Liter^{-1} water at 25 days interval, **T_3**= Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water at 25 days interval, **T_4**= IPM (Nappy trap+ Hand Weeding+ Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water apply when necessary) and **T_5**= Ripcord 10 EC @ 1.0 ml Liter^{-1} water at 25 days interval and **T_6**= Untreated control**.** Both the year each treatment was started to apply 30 days after sowing (DAS).

Data were collected from different crops grown in jhum on the following parameters-

- Number of insect infested plants^{-1}m^{2}
- Number of healthy plants^{-1}m^{2}
- Number of insect leaves^{-1} stems^{-1} panicle^{-1} etc.
- Weather data- on temperature, relative humidity, and rainfall.
- Yield data
- Yield increase due to treatment applications over control.

3.4.2 Geographical location

The study was conducted in the Bandarban, Rangamati and Khagrachari hill districts of the CHT (Chittagong Hill Tracts). Geographically CHT the only extensive hilly area in Bangladesh lies in southeastern part of the country (21^{0} 25' N to 23^{0} 45' N latitude and 91^{0} 54' E to 92^{0} 50' E longitude) bordering Myanmar on the southeast, the Indian state of Tripura on the north, Mizoram in the east and Chittagong district on the west. The area of the Chittagong Hill Tracts is about 13, 295 km^{2}, which is approximately one-tenth of the total area of Bangladesh. The Chittagong Hill Tracts (CHT), combining three hilly districts of Bangladesh Rangamati, Khagrachari and Bandarban districts.The mountainous rugged terrain with deep forests, gives it a diverse character from rest of Bangladesh (Ministry of Chittagong Hill Tracts Affairs). Agroecologically, the region belongs to the northern and eastern hills of Bangladesh (FAO/ UNDP 1988).

3.4.3 Climate

Bangladesh has a sub-tropical humid climate. Heavy rainfall occurs in the monsoon and scanty in the other seasons. Three distinct cropping seasons existed in this area. The summer season starts in March and April and is characterized by high temperatures and humidity with occasional thunderstorms and cyclones. The rainy season starts in May and ends in October, and winter starts in November and ends in February (SRDI 2002). Based on long-term records (1961-1990) obtained from the Rangamati Weather Station, rain starts in February, gradually increase until July, and then decrease. About 90% of the total rainfall occurs during six months from May to October. The highest (627 mm) and lowest (4 mm) of rainfall occur in the months of July and January, respectively. Maximum 33°C and minimum 20°C temperatures were recorded in April and January. After the rainy season, a long drought starts which lasts for four to five months. Mean annual temperature and relative humidity of the region are around 25°C and 80%, respectively (FAO 1988).

3.4.3.1 Weather Data of the Experimental hill region

The meteorological data including maximum (Max.) and minimum (Min.) mean monthly temperature (°C), total rainfall (mm), and relative humidity (RH) during the crop growing period were recorded from the adjoining meteorological station of the Rangamati, from Ramgar Hill Research Station (BARI), Khagrachari and from SRDI regional station, Bandarban districts. Mean weather data from May to December during 2015 and 2016 at Bandarban, Rangamati and Khagrachari were given in the (Appendix 8.1-8.3)

3.4.4 Jhum experimental field preparation

Slashing of vegetation and subsequent burning in the dry season, followed by dibbling of seeds after the onset of rains (generally in April) are common in jhum cultivation system in the CHT. According to Dasgupta *et al*. 2008, Kazal and Tapan 2013, normally land is cleared of shrubs, herbs and undergrowth vegetation, leaving the trees intact and all crops are planted at the same time under zero-tillage condition. After the onset of rains, crop germination and establishment pick up fast and along with other weeds, the crop plants also grow vigorously.

3.4.5 Seed sowing and management practices

After preparation of all experimental plots, lands were tilled as per treatments and jhum seeds were sown by a dibbling method on 15th May 2015 and due to heavy rain first sowing were done during 5th June 2016. Fertilizers were applied as per farmer’s practice.

3.4.6 Irrigation and water management

Jhum cultivation method is fully depends on rain water or rain fed condition. In the hilly crop cultivation (mixed or solo fruit production, spices etc.) water scarcity is a major problem in specially the months from October to March. In many places there is no facility like irrigation channels, water source for irrigation. The water source is far away from the crop field. Owing to inadequate irrigation channel they can’t irrigate the crop. So area under irrigation is not increasing significantly. The existing irrigation channels are not maintained properly. There are a few facilities for irrigation in the slope area. More over the farmers are not solvent to make irrigation facility by using irrigation machineries.

3.4.7 Intercultural operations and harvest

The experimental field was frequently monitored and necessary management practices such as weeding, drainage as required at the experimental fields. All sorts of activities done during the period from seedling raising to harvesting of jhum and rice-cotton intercropping in different experimental plots and were carried out by the farmers of respective experimental plot. Jhum crops are harvested one by one as they ripe successively from months of July to December.

3.4.8 Insecticide Chemical treatments

While a good pest management plan will start with preventative, cultural and other non-chemical methods, these are sometimes not completely effective on their own. In this case, different pesticides may be considered for diversified insect mite pest's management.

3.4.8.1 Spraying Marshal 20 EC or Carbosulfan 20% EC

Marshal 20% EC formulation of Carbosulfan, is a leader in providing broad spectrum insect control in several crops. Biochemistry of carbosulfan as cholinesterase inhibitor; activity is due to in vivo cleavage of the nitrogen-sulphur bond, resulting in conversion to carbofuran. Mode of action systemic insecticide with contact and stomach action.

3.4.8.2 Spraying Actara 25 WG

Actara 25 WG: Neonicotinoids active ingredient (Thiamethoxam) act on a specific protein in the brain of insect pests (the nicotinic acetylcholine receptor), inhibiting their feeding reflex. During food intake, healthy aphids stay nearly motionless on the leaf. After uptake of Thiamethoxam, the sucking insect stops feeding and even if death is delayed for 24 hours, the effects are comparable to knock-down compounds, since the feeding stop is irreversible. Affected sucking insects do not penetrate the plant tissue again. Actara® exhibits excellent trans-stemic (translaminar and systemic) movement in the plant tissue. It quickly penetrates the leaf to form a reservoir of active ingredient which results in extended residual control. Actara highly effective at low use-rates against a broad spectrum of sucking, soil and leaf-dwelling pests.

3.4.8.3 Spraying Voliam Flexi 300 SC

Voliam Flexi 300 SC: Mode of action: Voliam Flexi is a formula that combines the characteristics of two active ingredients with different mechanisms of action: chlorantraniliprole, belonging to the group of bisamides (anthramilic diamides), and thiamethoxam, of the neonicotinoid family. The insects affected by Voliam Flexi quickly stop feeding and moving, until they die. Voliam Flexi® is quickly absorbed by the plant tissues, mobilizing in a translaminar and systemic way, through the xylem. In this way, it gives residual protective action.

3.4.8.4 Ripcord 10 EC or Cypermethrin

Ripcord 10 EC: Cypermethrin is a non-systemic synthetic pyrethroid used as an insecticide in large-scale commercial agricultural applications as well as in consumer products for domestic purposes. It behaves as a fast-acting neurotoxin in insects. It is easily degraded on soil and plants but can be effective for weeks when applied to indoor inert surfaces. Exposure to sunlight, water and oxygen will accelerate its decomposition.

3.4.8.5 Spraying of insecticides

To ensure complete coverage of jhum plants and intercropping field's crops, spraying was done uniformly on the entire plant with Knapsack sprayer except untreated control. The spraying of insecticides were done in the afternoon to avoid bright sunlight, drift cause by the wind and killing of pollinating bees.

3.5. Jhumian traditional practice

3.5.1 Farmers practice

Traditional farming system is an ecologically based age-old farming system developed by ancient farmers through generations of their interaction with nature and natural resources for food, fodder and fiber. Indigenous knowledge is the knowledge of the indigenous people inhabiting different geographical regions of the world with their own language, culture, tradition, belief, folklore, rites and rituals. Mixed cultivation of rice with sparsely grown maize, legume crops, jobs tear (C*oix lacryma jobi*. L*)*, shorghum and ground vegetables, protects the diseases and pest of rice probably due to the physical barriers of intercrops in the movement of air borne prop gules, augmenting microclimate and humidity etc. Maize and sorghum not only provide food but also acts as perch for birds to feed on insects and pest of paddy in jhum field. Jhumian people also cultivate, cotton, sweet gourd, marpha, chenal, cucumber, ribbed gourd, white gourd, sesame, turmeric, cowpea, chili ("bindu morich"), taro, ginger, okra, brinjal and yard long bean, ufra sheem, bitter gourd, and country bean. Farmer also mention their jhum and hill crop were damaged by different biotic and abiotic factors. Among them insects, drought and heavy rainfall, weed, birds, wild pig, rodent (squirrel), monkey and deer.

3.5.2 Hand weeding

Thatch grass (*Imperita cylindrica*) and others common weeds in jhum fields often not only inhibits the healthy growth of paddy and other jhum crops, but also acts as alternate host of diseases and perches of brown plant hopper of paddy. Women were skilled in weeding without damaging planted crops. Five to eight women were seen to perform weeding along with household members in a jhum field. Farmers reported that if weeding is performed early, a better crop yield can be expected. For this reason they employ a number of labourers at one time to weed jhum fields.

3.5.3 Nappy Trap

Blended Shrimp fish is one of the local farmers practice to attracted insect pests and kill them by pressing by hand. The T_4 was selected based on results of the local farmer's practice in the jhum field.

3.5.3.1 Preparation of Nappy trap

Fishermen collected Shrimp fish (very small size) from the Bay of Bangal. Shrimp was primarily blended in Deki (A local blending machine made by wood) at the coastal areas of Bangladesh mainly Chokoria, Kutubdia of Cox's bazar district. Then primarily blended material were sun dried about two to three hours depending on the moisture content. Again primary materials blended by Deki until the fine crush and sun dried for four to six hours. For field application 50 gm nappy put inside the Ispahanee made plastic trap with sufficient amount of water to reach the level of the water marking of the trap. When the water height reduces under marking level due to evaporation, water was added to maintain the level. After twenty (20) days the nappy mixture were replaced by fresh new mixture of nappy. This trap was set in plot targeted for management practices by using nappy trap as treatments, starting from 30 days before full maturity and continued till the harvest.

3.6 Statistical Analysis

The data obtained were analyzed statistically after using appropriate transformation. Transformed data was analyzed by the method of analysis of variance as described by Gomez and Gomez (1984). Analysis of variance performed following Randomized Complete block design (RCBD) using computer package Statistix 10 version 10.0.1.5 software. The significance of difference between pair of means was tested by Tukey's honest significance test (HSD) at 5% level of significant.

CHAPTER IV

RESULTS AND DISCUSSION

4.1 Experiment 1. Survey on insect pests of the existing cropping system and farmer's practices for their management in hill tracts of Bangladesh

The experiments were conducted in the farmers' fields of jhum at Bandarban, Rangamati and Khagrachari from March 2014 to January 2015. The main target of the experiments was to assess the farmers' knowledge on insect pests' infestation in the existing cropping system and to find out the pattern of infestation of major insect pests in the hill districts. The result of the present study have been discussed and interpreted under the following sub-headings:

4.1.1 Farmers profile of age and education

Thus a total of 150 farmers are selected for interview and their individual plots were visited for survey (Table 4.1.1). The basic demographic data of each of the selected farmers were collected by administering a simple pre-designed and pre-tested checklist. In respect of age, 6.31% farmers were up to 30 years old, 48% farmers were in between 30 to 45 years, 45.69% farmers were above 45 years old and among them, 58.33% received primary level of education, 14.67% had secondary school level of education and the rest 27.00% were illiterate.

Table 4.1.1 Farmers profile of age and education of Khagrachari, Bandarban and Ranagamati districts during 2014-2015

<table>
<tr><th>Sl. No.</th><th>District</th><th>Upazila</th><th>Total no. of farmers</th><th>Age (Years)</th><th>Farmers</th><th>Education</th></tr>
<tr><td rowspan="3">1.</td><td rowspan="3">Khagrachari</td><td>Khagrachari Sadar</td><td rowspan="6">150</td><td rowspan="2">up to 30 years old</td><td rowspan="2">6.31%</td><td rowspan="2">58.33% primary level</td></tr>
<tr><td>Matiranga</td></tr>
<tr><td>Guimara</td><td rowspan="2">30 to 45 years old</td><td rowspan="2">48%</td><td rowspan="2">14.67% had secondary school level</td></tr>
<tr><td rowspan="2">2.</td><td rowspan="2">Bandarban</td><td>Bandarban Sadar</td></tr>
<tr><td>Rwangchari</td><td rowspan="2">above 45 years old</td><td rowspan="2">45.69%</td><td rowspan="2">27.00% were illiterate</td></tr>
<tr><td>3.</td><td>Rangamati</td><td>Kawkhali</td></tr>
</table>

4.1.2 Hill crops and farming Experience

Among the sample (150) farmers, 66.67% had experience of jhum farming whereas rest 33.33% didn't have experience of jhum farming but farmers had 10-50 years farming experience. Among the jhum farming experience 5.43% had the age of 5-15 years, 35.12% were 16-30 years old, 14.45% farmers were 31-45 years and 11.67% were more than 45 years old (Table 4.1.2).

Table 4.1.2 Farmers profile of farming and training of Khagrachari, Bandarban and Ranagamati districts during 2014-2015

<table>
<tr><th rowspan="2">Sl. No.</th><th rowspan="2">District</th><th rowspan="2">Upazila/ no. of farmers</th><th rowspan="2" colspan="2">Training</th><th colspan="2">Jhum farming experience</th></tr>
<tr><th>(Years)</th><th>%</th></tr>
<tr><td rowspan="3">1.</td><td rowspan="3">Khagrachari</td><td>Khagrachari Sadar/20</td><td>Received no Training</td><td>80.67%</td><td>5-15</td><td>5.43%</td></tr>
<tr><td>Matiranga/20</td><td rowspan="5">Received Pest management and other training (19.33%)</td><td rowspan="2">IPM (3.34%)</td><td>16-30</td><td>35.12%</td></tr>
<tr><td>Guimara/10</td><td>31-45</td><td>14.45%</td></tr>
<tr><td rowspan="2">2.</td><td rowspan="2">Bandarban</td><td>Bandarban Sadar/ 30</td><td rowspan="2">DAE (10.67%)</td><td>>45</td><td>11.67%</td></tr>
<tr><td>Rwangchari/20</td><td rowspan="2">No Jhum But farmers have 10-50 years farming experience</td><td rowspan="2">33.33%</td></tr>
<tr><td>3.</td><td>Rangamati</td><td>Kawkhali/50</td><td>CDB (5.32%)</td></tr>
</table>

Generally, Jhumian people cultivate HYV rice like BR24, BR26 and BRRI dhan 27 in the jhum system. They like locally adopted rice varieties for its some special characters like aroma, stickiness, long and slender grain and its lower yield. The local rice varieties like Boro dhan, Chakma Chikan, Hamarang, Prue, Company, Gallong, Cockrok and chili are being cultivated in the jhum system. They also cultivate mixed crops with rice to meet up the necessity of pulse, vegetables and fruits etc. The mixed crops are, rice, cotton, maize, kaon, sweet gourd, marpha, chenal, cucumber, bitter gourd, ribbed gourd, white gourd, sesame, turmeric, cowpea, chili ("bindu morich"), taro, ginger, okra, brinjal and yard long bean, ufra sheem, piper, bitter gourd, and country bean, banana. Similar informations were given by Barua 2016, Kazal and Tapan, 2013 and Mukul *et al.* (2011). Farmers also reported their jhum and hill crops were damaged by different biotic and abiotic factors. Among them, insects, drought and heavy rainfall, weed, birds, wild pig, rodent (squirrel), monkey and deer (Table 4.1.3-4.1.5).

4.1.2.1 Training on integrated pest management and others

On an average, 19.33% sample farmers received training whereas 80.67% did not receive any types of training. Among the farmers those who received training only 3.34% acknowledged integrated pest management, 5.32% received training from Cotton Development Board (CDB) and 10.67% training received from Department of Agricultural Extension (DAE) (Table 4.1.3-4.1.5).

4.1.3 Spray frequency, time and consultation

4.1.3.1 Bandarban hill district

In relation of pests' control 50% farmers of two Upazila of Bandarban hill district (Bandarban Sadar and Rwangchari) didn't spray any sort of chemical insecticides, whereas rest 50% used chemicals for their crop management on jhum and other crops in the hill slope. Among the chemical pesticides they sprayed 1-3 times with the consultation through pesticide retailer (80%), with DAE official (10%) and rest 10% taken suggestion from other farmers of Bandarban Sadar Upazila. While the Rwanchari farmers applied pesticide as suggested by retailer (20%), 50% farmers advised by DAE official, (20%) from cotton development official or scientific assistant and rest (10%) taken suggestion from other farmers. Among the farmers using chemical inesecticides like Acymix, Voliam flexi, Bajra, Kot, Suprathrin, Diazinon and Ripcord at Bandarban Sadar upazila whereas Suprathrin, Diazinon and Ripcord were used at Rwanchari. Jhumian farmers were familiar with their traditional pest management system to suppress the insect pest and others. Among them, 30% and 35% used dead crab, snake and snail hanging; 20% and 8% spray neem leaf paste, 20% and 18% perching for insectivorous birds, 10% and 13% hand picking during weeding in jhum season and 20% and 22% depends on their popular nappi trapping at Bandarban Sadar and Rwanchari Upazila, respectively (Table 4.1.3).

4.1.3.2 Rangamati hill district

In relation of pests' control, 100% farmers of Kawkhali Upazila from Rangamati hill district used chemicals for their crop management for jhum and other crops in the hill slope. Among the chemical pesticides they sprayed 2-5 times with the consultation through retailer (50%), 40% through DAE official and rest 10% habitually taken suggestion from other farmers at Kawkhali Upazila. Among the chemical insecticides farmers used Diazinon, Ripcord, Malathion, Admire, Basudin, Sevin, Bajra, Kot and Actara at Kawkhali Upazila. Jhumian farmers were familiar with their traditional pest management system to suppress the insect pest and others. Among them 12% used perching against insectivorous birds, 10% farmers practiced hand picking during weeding and 05% depends on their popular nappi trap at Kawkhali Upazila while about 77% didn't used their traditional different practices. Instead their traditional practices they were familiar with pesticide used on their crops field to suppress insect pests' infestation (Table 4.1.4).

4.1.3.3 Khagrachari hill district

Again in relation of pests' control 100% farmers of three Upazila of Khagrachari hill district (Khagrachari Sadar, Matiranga and Guimara) used chemicals for their crop management on jhum and other crops in the hill slope. Among the chemical pesticides they sprayed 2-3 times by the consulting retailer (75%), 15% consulting DAE official and rest 10% took suggestion from other farmers at Khagrachari Sadar Upazila. While the farmers of Matiranga used pesticides as suggested by from retailer (45%), 20% suggested by DAE official, 20% farmers got instruction from cotton development officials or scientific assistant and rest 15% took suggestion from other farmers. While at Guimara 65% of them followed recommendation from pesticide retailer, 15% from DAE official, 12% from cotton development official or scientific assistant and rest 8% got suggestions from other farmers. Among the chemical insecticides, farmers useed Malathion, Furadan, Dursban, Actara, Ranithion, and Ripcord at Khagrachari Sadar upazila whereas Admire, Belt, Larvin, Ripcord, Actara, Suntaf and Sencor were used at Matiranga and at Guimara. The farmers frequently used (Fighter, Ripcord, Tufgar, Dursban, Cartap, Larvin and Malathion. Jhumian farmers were familiar with their traditional pest management system to suppress the insect pests and others. Among them 27%, 20% and 23% used dead crab, snake and snail hanging respectively, 07%, 06% and 09% sprayed tobacco leaf dust, 20%, 23% and 19% used perching for insectivorous birds, 12%, 21% and 23% used hand picking during weeding in the jhum season (14%, 22% and), dry fish trap (nil, 18% and 16%), onion paste sprayed (05%, nil and 04%), light trap (nil, 05% and 06%) coriander sprayed and (17%, nil and nil) depends on their popular nappi trap at Khagrachari Sadar, Matiranga and Guimara Upazila, respectively (Table 4.1.5).

Table 4.1.3 Farmer's information about insect pests of different crops in jhum and pest management practices of at Bandarban

Name of Upazila	Crops grown in jhum	Farmer's information on problems of jhum cultivation	Major insect pests	Insecticides	Traditional pest management system	Source of pest management information
Bandarban Sadar	Rice	• Insects-40% • Drought and heavy rainfall-30% • Weed- 40% • Bird-20% • Wild pig- 20% • Deer- 10%	Rice bug, Stem borer Grasshopper	50% farmers used insecticides for insect pest management of jhum crops. They spray 1-3 times. **<u>Insecticides used:</u>** • Acymix • Diazinon • Ripcord • Volume flexi • Bajra • Kot • Suprathrin	• Dead crab and snake, snail hanging – 30% • Spray neem leaf paste- 20% • Parching -20% • Hand picking - 10% • Nappi trap- 20%	• Pesticide retailer - 80% • DAE officer - 10% • Other farmers- 10%
	Cotton		Red cotton bug			
	Maize		Aphid			
	Sweet gourd, Marpha, Cucumber, Ribbed gourd, White gourd Snake gourd		Fruit fly, Red pumpkin beetle			
	Sesame		No information			
	Turmeric		No information			
	Cowpea		Aphid			
	Okra		No information			
	Chili		No information			
	Bean		Jassid			

Contd…

Table 4.1.3 (Contd.)

Name of Upazila	Crops grown in jhum	Farmer's information on problems of jhum cultivation	Major insect pests	Insecticides	Traditional pest management system	Source of pest management information
Rwangchari	Rice	• Insects- 50% • Drought and heavy rainfall-20% • Weed- 40% • Wild pig- 15% • Rodent- 10%	Rice bug Stem borer Grasshopper	50% farmers used insecticides for insect pest management of jhum crops. They spray 1-3 times. **<u>Insecticides used:</u>** • Suprathrin • Diazinon • Ripcord	• Dead crab and snake, snail hanging - 35% • Hand picking -22% • Spray neem leaf paste- 8% • Nappi trap- 22% • Parching- 13%	• Pesticide retailer - 20% • DAE officer - 50% • Cotton officer - 20% • Other farmers- 10%
	Cotton		Red cotton bug			
	Maize		Aphid			
	Sweet gourd, Marpha, Cucumber, Ribbed gourd, Snake gourd		Fruit fly, Red pumpkin beetle			
	Sesame		No information			
	Turmeric		No information			
	Ginger		No information			
	Okra		Jassid			
	Chili		No information			
	Brinjal		Shoot and fruit borer			

Table 4.1.4 Farmer's information about insect pests of different crops and pest management practices of at Rangamati

Name of Upazila	Crops grown by farmers	Farmer's information on problems of crops	Major insect pests	Insecticides	Traditional pest management system	Source of pest management information
Kawkhali	Rice	• Insects-80% • Weeds- 40%	Rice bug, Stem borer Grasshopper	100% farmers used insecticides for insect pest management of jhum crops. They spray 2-5 times. **Insecticides used:** • Diazinon • Ripcord • Malathion • Admire • Basudin • Sevin • Bajra • Kot • Actara	• Hand picking-10% • Nappi trap- 05% • Parching- 12% • None- 77%	• Pesticide retailer - 50% • DAE officer - 40% • Other farmers- 10%
	Maize		Aphid			
	Sweet gourd, Cucumber, Bitter gourd, Teasel gourd		Fruit fly, Red pumpkin beetle			
	Ginger		Rhizome fly			
	Turmeric		No information			
	Cowpea		Aphid			
	Okra		Jassid			
	Chili		No information			
	Bush bean		Aphid			
	Tomato		Whitefly			
	Cabbage		Cabbage caterpillar			
	Brinjal		Shoot and fruit borer			
	Radish		No infromation			

Table 4.1.5 Farmer's information about insect pests of different crops in jhum and pest management practices of at Khagrachari

Name of Upazila	Jhum crops	Farmer's information on problems of jhum cultivation	Major insect pests	Insect pest management practice	Traditional pest management system	Source of pest management information
Khagrachari Sadar	Rice	• Insects - 85% • Drought and heavy rainfall- 20% • Weed- 80% • Bird-80% • Monkey-60% • Squirrel- 20%	Rice bug, Stem borer Grasshopper	100% farmers used insecticides for insect pest management of jhum crops. They spray 2-3 times. **<u>Insecticides used:</u>** • Dursban • Malathion • Furadan • Ripcord • Actara • Ranithion	• Dead crab and snake, snail hanging – 27% • Spray tobacco leaf dust- 07% • Hand picking -12% • Nappi trap- 14% • Dry fish trap- 18% • Onion paste spray- 05% • Coriander spray- 17%	• Pesticide retailer - 75% • DAE officer - 15% • Other farmers- 10%
	Cotton		Red cotton bug			
	Maize		Aphid			
	Sweet gourd, Marpha, Cucumber, Ribbed gourd, White gourd		Fruit fly, Red pumpkin beetle			
	Sesame		No information			
	Turmeric		No information			
	Cowpea		Aphid			
	Okra		Jassid			
	Chili		No information			
	Cow pea		Aphid			
	Taro		No information			

Contd……..

Table 4.1.5 (Contd.)

Name of Upazila	Jhum crops	Farmer's information on problems of jhum cultivation	Major insect pests	Insect pest management practice	Traditional pest management system	Source of pest management information
Matiranga	Rice	• Insects- 50% • Drought and heavy rainfall- 55% • Weed- 40% • Bird- 25% • Rodent- 20%	Rice bug Stem borer Grasshopper	100% farmers used insecticides for insect pest management of jhum crops. They spray 2-3 times. **<u>Insecticides used:</u>** • Admire • Belt • Larvin • Ripcord • Actara • Suntaf • Sencor •	• Dead crab and snake, snail hanging – 20% • Light trap-05% • Spray tobacco leaf dust- 06% • Parching for insectivorous birds-23% • Hand picking - 21% • Nappi trap- 25%	• Pesticide retailer - 45% • DAE officer - 20% • Cotton officer - 20% • Other farmers- 15%
	Cotton		Red cotton bug Bollworm			
	Maize		Aphid			
	Sweet gourd, Marpha, Cucumber, Ribbed gourd		Fruit fly, Red pumpkin beetle			
	Sesame		No information			
	Turmeric		No information			
	Ginger		No information			
	Okra		Jassid			
	Chili		No information			
	Brinjal		Shoot and fruit borer			
	Banana		Banana Shoot and fruit weevil			

Contd…

Table 4.1.5 (Contd.)

Name of Upazila	Jhum crops	Farmer's information on problems of jhum cultivation	Major insect pests	Insect pest management practice	Traditional pest management system	Source of pest management information
Guimara	Rice	• Insects- 60% • Drought and • heavy rainfall- 80% • Weeds- 10% • Rodents- 5	Rice bug Stem borer Grasshopper	100% farmers used insecticides for insect pest management of jhum crops. They spray 2-3 times. **<u>Insecticides used:</u>** • Fighter • Ripcord • Tufgar • Dursban • Cartap • Larvin • Malathion	• Dead crab and snake, snail hanging - 23% • Spray tobacco leaf dust- 09% • Parching for insectivorous birds,- 19%, • Hand picking -23% • Dry fish trap -16% • Light trap -06% • Onion paste spray - 04%,	• Pesticide retailer - 65% • DAE officer - 15% • Cotton officer - 12% • Other farmers- 8%
	Cotton		Red cotton bug Bollworm			
	Maize		Aphid			
	Sweet gourd, Marpha, Ribbed gourd		Fruit fly, Red pumpkin beetle			
	Turmeric		No information			
	Okra		Jassid			
	Brinjal		Shoot and fruit borer			
	Taro		No information			
	Chili		No information			
	Cowpea		Aphid			

4.1.4 Pest complex of jhum and hill cultivation and their intensity of incidence in different farmer's jhum and intercrop fields at hill slope of three hill districts of Bangladesh

Table 4.1.6-4.1.10 revealed those insect pests of cotton observed in jhum and rice-cotton intercropping at Bandarban, Rangamati and Khagrachari hill districts, their nature of damage, infestation percentage and pest status. Among the 11 insect pests on cotton, red cotton bug, cotton jassid and leaf roller are nominated as major pests as their infestation were prominent and easily visible by Jhumian people while others were considered as minor insect pests (Table 4.1.7). Among the five common rice insect pests at jhum and rice-cotton intercrop only rice green leaf hopper found as minor insect while other four (rice bug, rice leaf roller/folder, rice grasshopper, rice yellow stem borer and rice green leaf hopper) designated as major for their infestation and seasonal incidence comperatively higher (Table 4.1.6). Among eight insect pests found in the jhum cucurbit crops, between them cucurbit fruit fly (*Bactrocera cucurbitae* Coquillett), and red pumpkin beetle (*Raphidopalpa foveicollis* (Lucas) were designated as major insects and which cause maximum damage. On the other hand, rest 6 insect pests and their infestation percentage were moderate to insufficient thus considered as minor insect pests (Table 4.1.8). Another popular local hill sesame (Hill Till) crops and their insect infestation were very scanty thus all three insect pests were nominated as minor insect pests (Table 4.1.9). Whereas in jhum maize were damaged by five insect pests among them only one insect aphid infestation and their presence on maize leaves throughout the season and were considered as major insect pest while others considered as minor insects (Table 4.1.10). During survey, Jhumian people reported that their maize cob was severely damaged by cob eating bird, wild pig, deer, monkey, rodent, jungle fow, and squirrel. Farmers were very worried about hill rates as they were notorious for devastating rice crop particularly. When rates population increase comparatively higher. Jhumian people also mentioned that the crop damage were commonly resulted due to bird, wild pig, deer, monkey, rodent, jungle fow, and squirrel other than insect pests. They also found that different weeds as one of the major problem for jhum crops cultivation and caused 10-80% crop loss for their traditional cultivation and also served as insects' disease habitat.

Table 4.1.6 List of insect pests of rice observed in jhum and rice-cotton intercropping at hill districts, their nature of damage, infestation percentage and pest status

Sl. No.	Common name	Scientific name	Order: Family	Infestation % (Mean±SE)	Status
1.	Rice yellow stem borer	*Scirpophaga incertulas* Walker	Lepidoptera: Pyralidae	6.67±1.53	Major
2.	Rice leaf roller/ folder	*Cnaphalocrocis medinalis* (Guenee)	Lepidoptera: Pyralidae	9.67±1.15	Major
3.	Rice green leaf hopper	*Nephotettix* spp.	Homoptera: Cicadellididae	2.33±1.53	Minor
4.	Rice bug	*Leptocorisa acuta* (Thunberg)	Hemiptera: Alydidae	11.00±2.00	Major
5.	Rice grass hopper	*Hieroglyphus banian* (Fabricius)	Orthoptera: Acrididae	9.33±1.53	Major

Table 4.1.7 List of insect pests of cotton observed in jhum and rice-cotton intercropping at Bandarban, Rangamati and Khagrachari hill districts, their nature of damage, infestation percentage and pest status

Sl. No.	Common name	Scientific name	Order: Family	Nature of damage	Infestation % (Mean±SE)	Status
1.	Aphid	*Aphis gossypii* Glover	Homoptera: Aphididae	Nymph and adult suck the cell sap from tender shoots, leaves, flower buds, flowers, young bolls	3.33±1.53	Minor
2.	Spiraling whitefly	*Aleurodicus dispersus* (Russell)	Homoptera: Aleyrodidae	Nymph and adult suck the cell sap from ventral surface of leaves	2.00±1.73	Minor
3.	Cotton whitefly	*Bemicia tabaci* (Gennadius)	Homoptera: Aleyrodidae	Nymph and adult suck the cell sap from leaves and shoots	1.67±1.15	Minor
4.	Cotton jassid	*Amrasca biguttula* (Ishida)	Homoptera: Cicadellidae	Nymph and adult suck the cell sap from leaves and shoots	14.67±3.51	Major
5.	Red cotton bug	*Dysdercus cingulatus* (Fabricius)	Hemiptera: Pyrrhocoridae	Nymph and adult suck the cell sap from cotton bolls	66.67±15.28	Major
6.	Leaf roller	*Sylepta derogata* (Fabricius)	Lepidoptera: Pyralidae	Larvae roll and feed on cotton leaves	11.33±3.21	Major
7.	Cotton semi looper	*Trache notabilis* (Walker)	Lepidoptera: Noctuidae	Larvae feed on cotton leaves	6.00±3.61	Minor
8.	Spotted bollworm	*Earias* spp.	Lepidoptera: Noctuidae	Larvae bore cotton bolls	3.33±3.21	Minor
9.	Blister beetle	*Mylabris pustalata* (Thunberg)	Coleoptera: Meloidae	Adult feeds on cotton flower	5.00±3.00	Minor
10.	Bark feeding beetle	*Anoplophora sp.*	Coleoptera: Cerambycidae	Adult feeds on bark of cotton plants	4.67±2.52	Minor
11.	Cotton grasshopper	*Melanoplus* spp.	Orthoptera: Acrididae	Nymph and adult feed on foliage	6.67±1.53	Minor

Table 4.1.8 List of insect pests of cucurbits observed in jhum at Bandarban, Rangamati and Khagrachari hill districts, their nature of damage, infestation percentage and pest status

Sl. No.	Common name	Scientific name	Order: Family	Nature of damage	Infestation % (Mean±SE)	Status
1.	Red pumpkin beetle	*Raphidopalpa foveicollis* (Lucas)	Coleoptera: Crysomelidae	Adults feed on leaves	14.67±2.52	Major
2.	Red pumpkin beetle	*R. frontalis* (Baly)	Coleoptera: Crysomelidae	Adult feed on leaves	3.67±2.08	Minor
3.	Epilachna beetle	*Epilachna dodecastigma* Wiedemann	Coleoptera: Coccinellidae	Grubs and adults feed on leaves and skeletonize them	7.00±2.00	Minor
4.	Cucurbit fruit fly	*Bactrocera cucurbitae* Coquillett	Diptera: Tephritidae	Adults bore fruit during egg laying and larvae feed on internal soft tissue of fruits	27.67±2.52	Major
5.	Whitefly	*Bemicia tabaci* (Gennadius)	Homoptera: Aleyrodidae	Nymph and adult suck the cell sap from	2.00±1.00	Minor
6.	Pentatomid bug/ Stink bug	*Neazara viridula* Linnaeus	Hemiptera: Pentatomidae	Nymph and adult suck the cell sap from young leaves, petioles and stems	6.00±3.61	Minor
7.	Leaf minor	*Liriomyza munda* Frick	Diptera: Agromyzidae	Larvae puncture and make serpentine mines inside leaves	5.33±2.08	Minor
8.	Jassid	*Amrasca biguttula* (Ishida)	Homoptera: Cicadellidae	Nymph and adult suck the cell sap	3.00±1.00	Minor

Table 4.1.9 List of insect pests of sesame observed in jhum at Bandarban, Rangamati and Khagrachari hill districts, their nature of damage, infestation percentage and pest status

Sl. No.	Common name	Scientific name	Order: Family	Nature of damage	Infestation % (Mean±SE)	Status
1.	Stink bug	*Nezara viridula* (Linnaeus)	Hemiptera: Pentatomidae	Nymphs and adults suck the cell sap from leaves	4.67±2.08	Minor
2.	Hairy caterpillar	*Spilarctia obliqua* (Walker)	Lepidoptera: Arctiidae	Larvae feed on leaves	1.67±0.58	Minor
3.	Hawk moth	*Acherontia styx* (Westwood)	Lepidoptera: Sphingidae	Larvae feed on leaves	3.00±1.00	Minor

Table 4.1.10 List of insect pests of maize observed in jhum at Bandarban, Rangamati and Khagrachari hill districts, their nature of damage, infestation percentage and pest status

Sl. No.	Common name	Scientific name	Order: Family	Nature of damage	Infestation % (Mean±SE)	Status
1.	Aphid	*Rhopalosiphum maidis* (Fitch)	Homoptera: Aphididae	Nymphs and adults suck the cell sap from leaves, shoot, cobs	10.33±2.08	Major
2.	Stem borer	*Chilo partellus* (Swinhoe)	Lepidoptera: Noctuidae	Larvae bore into the stems and cobs	3.00±1.00	Minor
3.	Cutworm	*Agrotis* spp.	Lepidoptera: Noctuidae	Larvae cut the base at seedling stage	4.67±2.52	Minor
4.	Blister beetle	*Mylabris* sp.	Coleoptera: Meloidae	Adult feed on leaves	2.00±1.00	Minor
5.	Leaf weevil	*Myllocerus discolor* Boheman	Coleoptera: Curculionidae	Adults feed on leaf margin puncturing a number of closely arranged irregular holes.	5.00±2.00	Minor

4.2. Experiment 2. Identification of common insect pests found in jhum and rice-cotton intercropping system

The experiments was conducted in the farmers' fields of jhum at Bandarban, Rangamati and Khagrachari during 2015 and 2016. Field data were collected from farmer's field of jhum and rice-cotton intercropping of different Jhum crops; insect pests associated with it and sequence of their appearence on the crop, the insect pest succession was formulated. The result of the present study have been discussed and interpreted under the following sub-headings:

4.2.1. Insect mite pests of rice and their mean percentage of infestation

Mean percentage of infestation, life stage, infested plant parts and their diversity of insect and mite pests of rice grown in Jhum fields and rice crop in intercrop field were recorded after rice plant arises till to before harvesting of rice crop from farmers fields of Bandarban, Rangamati and Khagrachari districts and been discussed below:

During both years the list of insect mite pests of rice recorded from untreated jhum and intercrop field at Bandarban, Rangamati and Khagrachari of both 2015 and 2016 has been shown in Table 4.2.1. Rice plant serves as a host for a wide range of insect orders. Many foliage feeding, stem feeding, and grain sucker insects belong to six arthropod orders recorded 48 insects. Insects belonging to the orders Hemiptera, Orthoptera, Lepidoptera, Coleoptera, Isoptera and Blattodea. Important 17 insect taxa including the phloem-feeders within the order of Hemiptera. These include members of the hemipteran family's Aleyrodidae (whiteflies), Delphacidae (planthoppers), Cicadellidae (leafhoppers) Pentatomidae, Coreidae, and Lygaeidae that are sometimes referred to as the most common pests at all Bandarban, Rangamati and Khagrachari experimental Jhum field during 2015-2016. Again second highest (14 species) was recorded from important insect order Orthoptera comprise families of Acrididae, Tetrigidae, Gryllidae, Tettigoniidae and Gryllotalpidae represented as foliage feeder on rice plant at Jhum field and followed by insect order consisting of 11 insect of Lepidoptera comprehend families of Noctuidae, Pyralidae, Pyrausdtidae, Crambidae, Nymphalidae and Hesperiidae. Among the 6 insect orders, Coleoptera includes only 2 families (Chrysomelidae and Curculionidae) with two species are foliage feeder. Whereas orders Blattodea and Isoptera both comprise family (Termitidae) with four insects those are root and foliage feeder respectively.

Among the 48 species of insect mean percentage of infestation was recorded with the variables. Leaf beetles (*Lilioceris lilii* Scopoli) mean percentage of infestation at both hill experimental field of Bandarban and Rangamati was 19.80% and 16.61% respectively however at Khagrachari mean percentage of infestation was very scanty (0.68%) and insignificant in comparison to other two hill districts during 2016. Among the phloem-feeders (green leafhopper, white planthopper, white-backed planthopper, brown planthopper, zigzag leafhoppers, orange-headed leafhopper and Jikadia leafhopper) their mean percentage of infestation were 7.92%, 6.24% and 5.63%, respectively at Bandarban, Rangamati and Khagrachari experimental field during 2015-2016. Result revealed that phloem-feeders hemipteran insects' infestation was also significant at all the three hill districts though there were not found any viral contamination among the Jhum rice plant. Again foliage feeding insects like field cricket, bush crickets, crickets and mole crickets had mean percent of infestation comparatively higher and were 7.12% and 6.12% at Khagrachari and Rangamati, respectively whereas at Bandarban less percent of infestation (4.05%). Result revealed that phloem-feeders at all experimental fields of hill district and Leaf beetles (*Lilioceris lilii* Scopoli) except Khagrachari were considered as major insect pests.

Among the insect pest of rice, different rice stem borers had percent infestation of 2.97%, 2.86% and 2.90% as well as the grain sucker rice bug had infestation of 2.60%1, 2.51% and 4.05% at Bandarban, Rangamati and Khagrachari experimental fields respectively. Also different bugs i.e., bug, shield bugs, rice black bug and green stink bug had similar rate of infestation and obtained 2.12%, 3.01% and 2.17% in that order. Other insect pest mentioned in the Table 4.1.1 including grain sucker and diverse bugs were considered as minor insect pests as their infestation level were moderate to low. Rice plants are often infested by various pests. Insects are a major constraint of rice production. Over 800 species of insects in rice ecosystems have been reported worldwide. Out of these, 100 species attack rice while rest are considered as friendly insects (Israt *et al*., 2016, Noor and Hossain 2016, Pathak 1970). Findings of the present experiment were agreement with the findings of (Alam 2013, Nasiruddin and Roy 2012, BRRI 2009, Fatema *et al*. 1999 and Kamal *et al*. 1993). They mentioned that most of the rice plant parts are exposed to pest attack from a period of sowing till the harvest.

Insect damage plant parts by chewing tissues, boring stems or sucking fluid saps from stem and grains. Almost 20 insects are considered as rice pests of economic importance that include stem borers, gall midge, defoliators and vectors like leafhoppers and plant hoppers that cause direct damages and transmit various diseases (Nasiruddin and Roy 2012, Sardesai *et al*. 2001 and Pathak and Khan 1994).

Table 4.2.1 List of insect mite pests of rice in jhum and intercrop field and their mean percentage of infestation levels at Bandarban, Rangamati and Khagrachari during 2015 -2016

Sl. No.	Common name	Scientific name	Systematic position	Dama -ge stage[1]	Infested plant parts	Mean % infestation (Mean±SD)			Status
						Bandar -ban	Ranga -mati	Khagra -chari	
1.	Rice bug	*Leptocorisa oratoria* (Fabricius)	Hemiptera: Alydidae	N, A	Suck sap leaf, grain	2.60±0.01	2.51±0.05	4.05±0.03	Minor
2.		*Leptocorisa acuta* (Thunberg)	Hemiptera: Coreidae	N, A					
3.		*Cletus* spp.							
4.	Pink rice stem borer	*Sesamia inferens* (Walker)	Lepidoptera: *Noctuidae*	L	Stem	2.97±0.02	2.86±0.02	2.90±0.01	Minor
5.	Rice stem borer	*Scirpophaga innotata* (Walker)	Lepidoptera: Pyralidae	L					
6.		*Scirpophaga auriflura*		L					
7.		*Chilo polychrysus* (Meyrick)		L					
8.		*Paraponyx* spp.		L					
9.	Yellow stem borer	*Scirpophaga incertulas* (Walker).	Lepidoptera: Pyrausdtidae	L					
10.	Rice ear-cutting caterpillar	*Mythimna separate* (Walker)	Lepidoptera: *Noctuidae*	L	Leaf, Panicle	0.04±0.011	0.06±0.03	0.02±0.01	Minor
11.	Grasshopper	*Melanoplus* spp.	Orthoptera: Acrididae	N, A	Leaf	9.63±0.08	2.99±0.01	2.61±0.01	Minor
12.		*Atractomorpha spp.* (Fabricius)		N, A					
13.		*Omocestus viridulus (*Linnaeus*)*		N, A					
14.	Grasshopper / migratory locust	*Locusta migratoria manilensis* (Meyen)		N, A	Leaf				
15.	Indian grasshopper	*Acrida exaltata* (Walker)		N, A	Leaf				
16.	Grasshopper	*Oxya velox* (Fabricius)		N, A	Leaf				
17.		*Oxya chinensis* (Tunaberg)		N, A					
18.		*Hieroglyphus banian* (Fabricius)		N, A					
19.		*Hieroglyphus bettoni* (Kirby)		N, A					
20.	Pygmy grasshopper	*Paratettix* spp.	Orthoptera: Tetrigidae	N, A	Leaf				
21.	Rice leaf roller	*Cnaphalocrocis medinalis* (Guenee)	Lepidoptera: Crambidae	L	Leaf	1.18±0.01	0.83±0.01	0.43±0.01	Minor

Table 4.2.1 (Contd.)

Sl. No.	Common name	Scientific name	Systematic position	Dama-ge stage[1]	Infested plant parts	Mean % infestation (Mean±SD)			Status
						Bandar-ban	Ranga-mati	Khagra-chari	
22.	Leaf beetles	*Lilioceris lilii* (Scopoli)	Coleoptera: Chrysomelidae	A	Leaf	19.80±0.42	16.61±0.47	0.68±0.07	Major
23.	Rice root weevil	*Echinocnemus oryzae* (Marshall)	Coleoptera: Curculionidae	A	feed root and stem	0.02±0.001	0.04±0.01	0.01±0.01	Minor
24.	Termite wheat termite	*Pseudacanthotermes militaris* (Hagen)	Blattodea: Termitidae	N, A	feed root and stem	1.28±0.01	3.68±0.02	2.32±0.01	Minor
25.		*Microtermes obesi* (Holmgren)		N, A					
26.	Termite	*Odontotermes obesus* (Rambur)	Isoptera: Termitidae	N, A	feed root and stem				
27.		*Odontotermes brunneus* (Hagen)		N, A					
28.	Green leafhopper/ Leafhopper	*Nephotettix nigropictus* (Stal)	Hemiptera: Cicadellidae		Suck sap Leaf	0.47±0.01	0.44±0.03	0.41±0.01	Minor
29.		*Nephotettix virescens* (Distant)		N, A					
30.	White planthopper	*Tettigella spectra* (Distant)	Hemiptera: Cicadellidae	N, A	Suck sap Leaf	7.92±0.03	6.24±0.01	5.63±0.07	Minor
31.	White backed planthopper	*Sogatella furcifera* (Horváth)	Hemiptera: Delphacidae	N, A	Suck sap Leaf				
32.	*Brown planthopper*	*Nilaparvata lugens* (Stål)	Hemiptera: Delphacidae	N, A	Suck sap Leaf				
33.	Zigzag leafhoppers	*Recilia dorsalis* (Motschulsky)	Hemiptera: Cicadellidae	N, A	Suck sap Leaf				
34.	Orange-headed leafhopper	*Thaia oryzivora* (Ghauri)	Hemiptera: Cicadellidae	N, A	Suck sap Leaf				
35.	Jikadia leafhopper	*Jikadia olitoria* (Say)	Hemiptera: Cicadellidae	N, A	Suck sap Leaf				
36.	Rice black bug	*Scotinophara coaractata* (Fabricus)	Hemiptera: Pentatomidae	N, A	Suck sap Leaf	1.11±0.03	2.01±0.01	1.05±0.03	Minor

Damage stage*[1]: L, larva; N, nymph; A, adult** ***Contd…….

Table 4.2.1 (Contd.)

<table>
<tr><th rowspan="2">Sl. No.</th><th rowspan="2">Common name</th><th rowspan="2">Scientific name</th><th rowspan="2">Systematic position</th><th rowspan="2">Damage stage[1]</th><th rowspan="2">Infested plant parts</th><th colspan="3">Mean % infestation (Mean±SD)</th><th rowspan="2">Status</th></tr>
<tr><th>Bandar-ban</th><th>Ranga-mati</th><th>Khagra-chari</th></tr>
<tr><td>37.</td><td>Bug</td><td>Pachybrachius spp.</td><td>Hemiptera: Lygaeidae</td><td>N, A</td><td>Suck sap Leaf</td><td rowspan="5">2.12±0.023</td><td rowspan="5">3.01±0.04</td><td rowspan="5">2.17±0.011</td><td rowspan="5">Minor</td></tr>
<tr><td>38.</td><td>Shield bugs</td><td>Eysarcoris ventralis (Westwood)</td><td rowspan="4">Hemiptera: Pentatomidae</td><td>N, A</td><td>Suck sap Leaf</td></tr>
<tr><td>39.</td><td>Rice black bug</td><td>Antestia degenera (Walker)</td><td>N, A</td><td>Suck sap Leaf</td></tr>
<tr><td>40.</td><td rowspan="2">Green stink bug</td><td>Nezara viridula (Linnaeus)</td><td>N, A</td><td rowspan="2">Suck sap Leaf</td></tr>
<tr><td>41.</td><td>Eysarcoris ventralis (Westwood)</td><td>N, A</td></tr>
<tr><td>42.</td><td>Brush-footed butterflies</td><td>Melanitis leda ismene (Cramer)</td><td>Lepidoptera: Nymphalidae</td><td>L</td><td>Leaf</td><td rowspan="3">0.80±0.011</td><td rowspan="3">0.65±0.012</td><td rowspan="3">0.77±0.012</td><td rowspan="3">Minor</td></tr>
<tr><td>43.</td><td rowspan="2">Rice skipper</td><td>Pelopidas mathias (Fabricius)</td><td rowspan="2">Lepidoptera: Hesperiidae</td><td>L</td><td rowspan="2">Leaf</td></tr>
<tr><td>44.</td><td>Telicota augias (Linnaeus)</td><td></td></tr>
<tr><td>45.</td><td>Field cricket</td><td>Brachytrupes portentosus (Lichtenstein)</td><td>Orthoptera: Gryllidae</td><td>N, A</td><td>Leaf</td><td rowspan="4">4.05±0.23</td><td rowspan="4">6.12±0.12</td><td rowspan="4">7.12±0.101</td><td rowspan="4">Minor</td></tr>
<tr><td>46.</td><td>Bush crickets/ katydids</td><td>Conocephalus longipennis (Haan)</td><td>Orthoptera: Tettigoniidae</td><td>N, A</td><td>Leaf</td></tr>
<tr><td>47.</td><td>Crickets</td><td>Euscyrtus concinnus (Haan)</td><td>Orthoptera: Gryllidae</td><td>N, A</td><td>Leaf</td></tr>
<tr><td>48.</td><td>Mole crickets</td><td>Gryllotalpa orientalis (Burmeister)</td><td>Orthoptera: Gryllotalpidae</td><td>N, A</td><td>Root and Leaf</td></tr>
</table>

***Damage stage*[1]: L, larva; N, nymph; A, adult**

4.2.2 Insect and mite pests of sesame and their mean percent of infestation

Mean percent of infestation, life stage, infested plant parts and diversity of insect and mite pests of sesame grown in Jhum fields were recorded after sesame plant arises till before harvesting from farmers Jhum fields at Bandarban, Rangamati and Khagrachari districts and have been discussed below:

Both the years, the list of insect and mite pests of sesame recorded from untreated jhum fields at Bandarban, Rangamati and Khagrachari has been shown in Table 4.2.2. Sesame plant serves as a host for an extensive range of insect orders. Many foliage feeding, stem feeding, and leaf mining insect and mites belong to seven arthropod orders having 30 insect and mites were recorded. Insects belonging to the orders Hemiptera, Lepidoptera, Orthoptera, Coleoptera, Diptera and Thysanoptera and Acarina. A significant number (10) of insect taxa were counted as the phloem-feeders within the order of Hemiptera. These include members of the Hemipteran family of Aleyrodidae (whiteflies), Aphididae, Miridae, Cicadellidae (leafhoppers), Pyrrhocoridae, and Pentatomidae those are sometimes referred to as the most common sap-sucking insects' at all three hill districts during 2015-2016.

Again second highest number (7) was recorded from the order Lepidoptera covering the families of Noctuidae, Pyralidae, Sphingidae, Arctiidae, and Crambidae followed by order Coleoptera (4) include families only Chrysomelidae and Curculionidae as foliage, flower bud and twig feeders whereas the order Orthoptera (3) comprise only one family, Acrididae. Among the thirty insect and mite pest orders, Diptera (2) include families of Cecidomyiidae and Agromyzidae as internal leaf feeder. Furthermore, former consisted of gall fly, and their infestation percent were scanty (Bandarban 0.76%, Rangamati 0.34% and Khagrachari 0.84%) whereas leaf minor represented the family Agromyzidae only showing infestation of 1.65% on sesame leaf at Bandarban.

Thysanoptera comprising one family of Thripidae which showed the mean infestation percent on flower bud, flower and pod at Bandarban (4.03%), Rangamati (2.09%) and Khagrachari (3.76%). Two mites' of (Acarina) showed percent infestation on leaf, flower bud and flower by 2-spotted spider mites were Bandarban (3.12%), Rangamati (2.98%) and Khagrachari (3.09%), whereas other mite i.e., flat mite infestation percentage was very low. Among the 30 insect and mite the variable mean percentage of infestation was recorded. Leaf webber showed the mean percentage of infestation at Bandarban (12.63%), Rangamati (11.28%) and Khagrachari (18.59%), whereas different phloem-feeding bugs such as mirid bug, pod bug, bug, and green stink bug infestation rate at Bandarban were (9.73%), Rangamati (13.72%) and Khagrachari (11.33%) caused the highest level of infestation and considered as major insect pests. Other insect and mite pests also recorded and shown in Table 4.2.2

which include aphid, jassid, leaf beetles, thrips, hawk-moth, whitefly, leaf beetle and different grasshoppers and they were considered as minor insect pests as their infestation level were moderate to low at all three hill district of Bangladesh in both 2015 and 2016.

A similar finding was reported by Mahmoud 2012 earlier. He reported a total of 31 insect texa which were collected and identified during the survey. Insects recorded on the plants were belong to Orthoptera, Odonata, Hemiptera and Homoptera and natural enemies from Coleoptera, Hymenoptera, Neuroptera and Dictyoptera. The Hemipteran pest, Green stink bug, *Nezara viridula* (whose nymphs and adults were associated with flowers and leaves) comprised 13.22% in 2010 and 9.58% in 2011 of collected pest species, respectively (Mahmoud 2012). He also mentioned the main phloem-feeders associated with leaves and pods, was leafhopper- *Empoasca lybica*, as the most dominant with higher infestation (26.59%-29.94%).

Sesame is attacked by numerous insect and mite pests which reduce its yield both in quality and quantity. Thirty 30 species were identified as pest among the different insect and mite pests recorded. The highest number of insect pests were obtained from Heteroptera followed by Homoptera, Lepidoptera, Coleoptera and Thysanoptera. Out of 30 insect pests recorded, *Acherontia Styx, Spilarctia oblique, Nezara viridula, Dolycoris indicus, Orosius albicinctus* and *Bemisia tabaci* were the major (Thangjam and Vastrad 2018, Anonymous 2012, Nayar *et al*. 1986, Rai 1976).

Table 4.2.2 List of insect and mite pests of sesame in jhum field and their mean percentage of infestation levels at Bandarban, Rangamati and Khagrachari during 2015 -2016

Sl. No.	Common name	Scientific name	Systematic position	Damage stage[1]	Infested plant parts	Mean % infestation (Mean±SD)		
						Bandar -ban	Ranga -mati	Khagra -chari
1.	Aphid	*Aphis gossypii* (Glover)	*Hemiptera: Aphididae*	N, A	Suck sap leaf, Flower bud	5.55±0.03	6.20±0.04	4.290±0.2
2.		*Myzus persicae* (Sulzer)						
3.	Jassid	*Empoasca lybica* (*de Berg.*)	Hemiptera: Cicadellidae	N, A	Suck sap leaf, Flower bud	5.38±0.01	4.96±0.01	4.96±0.01
4.		*Empoasca terminalis* (Dist.)						
5.	Leaf hopper	*Orosius albicinctus* (Distant)	Hemiptera: Cicadellidae	N, A	Suck sap leaf, twig	3.63±0.06	2.28±0.01	3.59±0.01
6.	leaf beetles	*Lilioceris lilii* (Scopoli)	Coleoptera: Chrysomelidae	A	Leaf	5.22±0.02	4.26±0.02	3.45±0.01
7.	Leaf minor	*Agromyza* sp. (Fallen)	Diptera : Agromyzidae	L	Leaf	1.65±0.01	-	-
8.	Leaf and pod caterpillar	*Antigastra catalaunalis* (Dup.)	Lepidoptera: Pyralidae	L	Leaf, pod	1.12±0.03	2.13±0.04	2.14±0.01
9.	Gall fly	*Asphondylia sesame* (Felt)	Diptera: Cecidomyiidae	L	Leaf, pod	0.76±0.01	0.34±0.01	0.84±0.02
10.	Melon thrips	*Thrips palmi* (Karny)	Thysanoptera: Thripidae	N, A	Leaf, flower pod	4.03±0.03	2.09±0.07	3.76±0.03
11.	Thrips	*Frankliniella schultzei* (Trybom)		N, A	Leaf, flower pod			
12.	Hawk-moth	*Acherontia styx* (Westwood)	Lepidoptera: Sphingidae	L	Leaf, twig	3.94±0.03	3.80±0.06	3.65±0.08
13.		*Ambulyx substrigilis* (Westwood)						
14.	Hairy caterpillar	*Spilarctia oblique* (Walker)	Lepidoptera: Arctiidae	L	Leaf	1.67±0.02	2.01±0.01	0.67±0.01
15.	Semilooper	*Plusia orchalcea* (Fab.)	Lepidoptera: Noctuidae	L	Leaf	1.45±0.07	2.92±0.05	2.01±0.05
16.	Whitefly	*Bemisia tabaci* (*Gennadius*)	*Hemiptera:* Aleyrodidae	N, A	Suck sap leaf, twig	3.85±0.04	4.11±0.02	2.98±0.01

Damage stage[1]*: L, larva; N, nymph; A, adult** ***Contd……

Table 4.2.2 (Contd.)

Sl. No.	Common name	Scientific name	Systematic position	Damage stage[1]	Infested plant parts	Mean % infestation (Mean±SD)		
						Bandar-ban	Ranga-mati	Khagra-chari
17.	Mirid bug	*Cyrtopeltis tenuis* (Reuter)	*Hemiptera: Miridae*	N, A	Suck sap leaf, twig and flower bud	9.73±0.03	13.72±0.01	11.33±0.02
18.	Pod bug	*Pyrrhocoris* sp.	*Hemiptera*: Pyrrhocoridae	N, A				
19.	Bug	*Eusarcocoris ventralis* (Westwood)		N, A				
20.	Green stink bug	*Nezara viridula* (Linnaeus)	*Hemiptera*: Pentatomidae	N, A				
21.	Grasshopper	*Acrotylus insubricus* (Scopoli)	Orthoptera: Acrididae	N, A	Leaf	4.78±0.05	5.08±0.02	3.92±0.02
22.	Green grasshopper	*Heteracris littoralis* (Ramb.)		N, A				
23.	Grasshopper	*Atractomorpha crenulata* (Fabricius)	Orthoptera: Acrididae	N, A	Leaf			
24.	Leaf webber	*Antigastra catalaunalis* (Duponchel)	Lepidoptera: Crambidae	L	Leaf	12.63±0.07	11.28±0.02	18.59±0.01
25.	Black cutworm	*Agrotis ipsilon* (Hufnagel)	Lepidoptera: Noctuidae	L	Leaf	2.08±0.06	2.04±0.01	2.78±0.05
26.	Black weevil	*Cyrtozemia cognata* (Marshall)	Coleoptera: Curculionidae	A	Flower bud, leaf, twig	0.96±0.02	0.78±0.02	0.45±0.01
27.	Leaf beetle	*Monolepta signata* (Oliv.)	Coleoptera: Chrysomelidae	A	Flower bud, leaf, twig	3.98±0.05	3.01±0.04	4.12±0.05
28.	Grey weevil	*Myllocerus maculosus* (Desb.)	Coleoptera: Curculionidae	A	Flower bud, leaf, twig	1.06±0.05	0.99±0.01	1.12±0.04
29.	Two-spotted spider mite	*Tetranychus urticae* (Koch)	Acarina: Tetranychidae	N, A	Leaf, flower, twig	3.12±0.08	2.98±0.05	3.09±0.01
30.	Flat mite	*Brevipalpus phoenicis* (Geijsker)	Acarina: Tenuipalpidae	N, A	Leaf	0.07±0.01	0.09±0.01	0.06±0.02

***Damage stage*[1]: L, larva; N, nymph; A, adult**

4.2.3 Insect and mite pests of country bean and their rate of infestation

Percent of infestation, life stage, infested plant parts and their diversity of insect and mite pests of country bean grown in jhum fields were recorded from seedling till before harvesting pods of country bean from farmer's jhum fields at Bandarban, Rangamati and Khagrachari districts. The results were discussed below:

In both the years the list of insect and mite pests of country bean recorded from untreated jhum field at Bandarban, Rangamati and Khagrachari has been shown in Table 4.2.3. Country bean plant serves as a host for a widespread range of insect of different orders. Many foliage feeding, stem feeding, pod borer and leaf minor insect and mites belong to seven orders were recorded (22). Insects belonging to the orders Lepidoptera, Hemiptera, Coleoptera, Diptera, and mites order Acarina. Significant insect taxa including the foliage as well as internal feeder within the order of Lepidoptera (10 species). These include members of the lepidopteran families of Crambidae, Pyralidae, Arctiidae, Hesperiidae, Erebidae and Terophoridae and these were sometimes referred to as common insect pests.

Among the six families of Lepidoptera, 3 insects of bean pod borer represent 2 families of Crambidae and Pyralidae having combined percent infestation were 24.23% (Bandarban), 27.08% (Rangamati) and 29.22% (Khagrachari) revealed the maximum level of infestation and considered as major insect pests. Whereas other lepidopteran insects such as hairy caterpillar, bean leaf roller, semilopper, leaf-eating caterpillar and plume moth were considered as minor insect pests as their infestation level were moderate to low in both the years (2015-2016) at all the three hill district of Bangladesh.

Significant insect taxa including the phloem-feeders within the order of Hemiptera (6). These include members of the hemipteran families of Aphididae, Pentatomidae, Plataspidae, Cicadellidae, Coreidae, Membracidae, and these were sometimes referred to as communal sap-sucking insects' at all the three hill districts of Bangladesh during 2015-2016. Among six different insects, black bean aphid belong to family Aphididae having infestation rate of 16.65% (Bandarban), 18.04% (Rangamati) and 17.08% (Khagrachari) caused the highest level of infestation among the phloem-feeders and considered as major insect pests.

Other five insects belongs to the hemiptera order such as consisting of green sting bug, bean bug, jassid, coreid bug and hooded hopper and they were considered as minor insect pests as their infestation level were moderate to low during 2015-2016 at all the three hill districts of Bangladesh. Rest infesting order i.e. Coleoptera and Diptera included these families of Chrysomelidae, Curculionidae and Agromyzidae, and these comprised 4 insects, as well as 2 species of spider mite and they were considered as minor insect and mite pests as their infestation level were moderate to low.

In India, more than 57 species of arthropods attacked on country bean has been reported (Govindan 1974). Whereas in Myanmar, country beans was infested by 14 arthropod pests (Shroff 1920). Findings of the present experiment were in agreement with the findings of Hooks and Fereres 2006, Butani and Jotwani 1984. They reported that aphid was the most common and major pest all over the world which is responsible for feeding damage and transmission of plant virus.

Table 4.2.3 List of insect and mite pests of country bean in jhum field and their mean percentage of infestation levels at Bandarban, Rangamati and Khagrachari during 2015 -2016

Sl. No.	Common name	Scientific name	Systematic position	Damage stage[1]	Infested plant parts	Mean % infestation (Mean±SD)		
						Bandar -ban	Ranga -mati	Khagra -chari
1.	Black bean aphid	*Aphis fabae* (Scopoli)	Hemiptera: Aphididae	N, A	Flower bud, leaf, twig	16.65± 0.34	18.04±0.71	17.08±0.45
2.	Bean pod borer	*Maruca vitrata* (Fabricious)	Lepidoptera: Crambidae	L	Flower bud, pod	24.23±0.23	27.08±0.44	29.22±0.29
3.		*Helicoverpa armigera* (Hübner)		L				
4.		*Maruca testularis* (Geyer)	Lepidoptera: Pyralidae	L				
5.	Hairy catterpillar	*Spilarctia oblique* (Walker)	Lepidoptera: Arctiidae	L	Leaf	3.89±0.09	5.23±0.05	1.87±0.03
6.	Bean leaf roller	*Urbanus proteu* (Linnaeus)	Lepidoptera: Hesperiidae	L	Leaf	3.98±0.06	2.34±0.03	2.11±0.2
7.	Leaf minor	*Liriomyza sativae* (Blanchard)	Diptera: Agromyzidae	N, A	Leaf	1.87±0.12	0.98±0.18	1.04±0.03
8.	Semilopper	*Achaea janata* (Linnaeus)	Lepidoptera: Erebidae	L	Leaf	0.76±0.05	0.67±0.02	0.34±0.03
9.	Green semilooper	*Plusia oricalchea* (Fabricius)	Lepidoptera: Pyralidae	L	Leaf			
10.	Green sting bug	*Nezara viridula* (Linnaeus)	Hemiptera: Pentatomidae	N, A	Suck sap Flower bud, leaf, twig	0.34±0.08	0.98±0.04	0.52±0.01
11.	Leaf eating caterpillar	*Amsacta albistriga* (Walker)	Lepidoptera: Erebidae	L	Leaf	0.12±0.01	0.21±0.01	0.15±0.011
12.	Bean bug	*Coptosoma cribraria* (Fabricius)	Hemiptera: Plataspidae	N, A	Suck sap Flower bud, leaf, twig	2.08±0.03	3.01±0.011	1.09±0.03
13.	Leaf eating caterpillar	*Plusia oricalchea* (Fabricius)	Lepidoptera: Pyralidae	L	Leaf	0.22±0.01	0.24±0.02	0.55±0.012

***Damage stage*[1]: L, larva; N, nymph; A, adult**

Contd…

Table 4.2.3 (Contd.)

Sl. No.	Common name	Scientific name	Systematic position	Damage stage[1]	Infested plant parts	Mean % infestation (Mean±SD)		
						Bandar-ban	Ranga-mati	Khagra-chari
14.	Jassid	*Empoasca decipiens* (Paoli)	Hemiptera: Cicadellidae	N, A	Suck sap Flower bud, leaf, twig	5.98±0.056	7.66±0.46	9.12±0.23
15.	Coreid bug	*Leptoglossus* spp.	Hemiptera: Coreidae	N, A	Suck sap Flower bud, leaf, twig	0.25±0.04	0.33±0.07	0.31±0.02
16.	Hooded hopper	*Leptocentrus Taurus* (Fabricius)	Hemiptera: Membracidae	N, A	Suck sap Flower bud, leaf, twig	0.19±0.01	0.22±0.05	0.11±0.01
17.	Leaf beetle	*Madurasia obscurella* (Jacoby)	Coleoptera: Chrysomelidae	A	Flower bud, leaf, twig	0.78±0.04	0.67±0.02	0.55±0.03
18.	Leaf weevil	*Blosyrus oniscus* (Olivier)	Coleoptera: Curculionidae	A	Flower bud, leaf, twig	0.22±0.05	0.27±0.01	0.18±0.04
19.	Spider mite	*Tetranychus urticae* (Koch)	Acarina: Tetranychidae	N, A	Suck sap Flower bud, leaf, twig	4.87±0.23	3.87±0.07	6.23±0.56
20.		*Tetranychus macfarlanei* (Baker and Pritchard)						
21.	Plume moth	*Sphenarches anisodactylus* (Walker)	Lepidoptera: Terophoridae	L	Leaf	0.17±0.05	0.20±0.06	0.33±0.02
22.	Flea beetle	*Altica lythri* (Aubé)	Coleoptera: Chrysomelidae	A	Leaf	0.87±0.05	0.34±0.02	0.44±0.01

***Damage stage*[1]: L, larva; N, nymph; A, adult**

4.2.4 Insect and mite pests of cowpea and their mean percentage of infestation

Percent infestation, life stage, infested plant parts and their diversity of insect and mite pests of cowpea grown in jhum fields were recorded from seedling to before harvesting pods of cowpea from farmers jhum fields at Bandarban, Rangamati and Khagrachari districts were discussed below:

The list of insect and mite pests of cowpea were recorded from untreated jhum field at Bandarban, Rangamati and Khagrachari for 2015 and 2016 and described in Table 4.2.4. Cowpea plant serves as a host for an extensive range of insect orders. Many foliage feeding, stem feeding, pod borer and leaf minor insect and mites belong to seven arthropod orders recorded 17 insect and mites. Insects belonging to the orders Hemiptera, Coleoptera, Lepidoptera, Diptera, Thysanoptera and mites (Acarina).

Considerable insect taxa including the phloem-feeders within the order of Hemiptera (6) on cowpea crop in jhum field were observed. These include members of the hemipteran families of Aphididae, Jassidae, Pentatomidae, Cicadellidae, Coreidae, Membracidae, and these were occasionally mentioned as the best mutual sap-sucking insects' at all three hill districts of Bangladesh during 2015-2016. Among six different insects aphid (*Aphis craccivora* Kosh) belonged to family Aphididae with mean percentage of infestation were 15.75% (Bandarban), 18.23% (Rangamati) and 12.97% (Khagrachari) caused the highest level of infestation among the phloem-feeders and considered as major insect pests. Other five insects belongs to the hemiptera order i.e., green jassid, green sting bug, coreid bug, leafhoppers and hooded hopper were considered as minor insect pests as their infestation level were moderate to low during 2015-2016 at all the three hill district of Bangladesh.

Again only 3 insect taxa including the foliage as well as internal feeder within the order of Lepidoptera include members of Crambidae and Noctuidae and these were sometimes referred to as common insect pests. Among the 2 families of each one insect of bean pod borer and greasy cutworms had percent infestation of 19.34% (Bandarban), 17.06% (Rangamati) and 21.34% (Khagrachari) and (Bandarban 7.98%, Rangamati 11.03% and Khagrachari 7.05%), respectively caused significant level of infestation and considered as major insect pests. Insect semilopper was considered as minor insect pests as their infestation level were 0.34%, 0.56% and 0.22% which were very little during 2015-2016 at all the three hill districts. Rest infesting orders i.e. Coleoptera, Thysanoptera and Diptera included families of Chrysomelidae, Curculionidae, Thripidae and Agromyzidae respectively and these comprised six insects, as well as 2 spider mites. These were considered as minor insect and mite pests as their infestation level were moderate to low. Yield losses of 10-100% and crop failure occur due to the feeding activities of a wide range of insect pests which attack cowpea crop in the field at different growth stages (Singh and Emden 1979). The cowpea aphid, *A. craccivora* is a key pest of cowpea in the field. Yield losses from feeding activity of *A. craccivora* were estimated between 13 to 100%. They also mentioned the major part of damages is related to indirect damage (Shoyinka *et al*. 1997).

Table 4.2.4 **List of insect and mite pests of cowpea in jhum field and their mean percentage of infestation levels at Bandarban, Rangamati and Khagrachari during 2015-2016**

Sl. No.	Common name	Scientific name	Systematic position	Damage stage[1]	Infested plant parts	Mean % infestation (Mean±SD)		
						Bandar-ban	Ranga-mati	Khagra-chari
1.	Green jassid	*Empoasca kerri* (Pruthi)	Hemiptera: Jassidae	N, A	Flower bud, leaf, twig	5.07±0.01	3.87±0.03	4.33±0.06
2.	Green sting bug	*Nezara viridula* (Linnaeus)	Hemiptera: Pentatomidae	N, A	Flower bud, leaf, twig	2.89±0.05	3.11±0.08	3.76±0.04
3.	Coreid bug	*Leptoglossus* spp.	Hemiptera: Coreidae	N, A				
4.	Aphids	*Aphis craccivora* (Kosh)	Hemiptera: Aphididae	N, A	Flower bud, leaf, twig	15.75±0.05	18.23±0.03	12.97±0.08
5.	Thrips	*Megalurothrips distalis* (Karny)	Thysanoptera: Thripidae	N, A		4.05±0.03	5.05±0.02	3.11±0.01
6.	Bean pod borer	*Maruca testulalis* (Geyer)	Lepidoptera: Crambidae	L	Flower bud, pod	19.34±0.11	17.06±0.08	21.34±0.44
7.	Leaf minor	*Liriomyza sativae* (Linnaeus)	Diptera: Agromyzidae	L	Leaf	0.72±0.01	0.93±0.02	1.04±0.01
8.	Greasy cutworms	*Agrotis ipsilon* (Hufnagel)	Lepidoptera: Noctuidae	L	Leaf, young twig	7.98±0.34	11.03±0.45	7.05±0.22
9.	Semilooper	*Diachrysia* spp.	Lepidoptera: Noctuidae	L	Leaf	0.34±0.03	0.56±0.01	0.22±0.01
10.	Leafhoppers	*Empoasca* spp.	Hemiptera: Cicadellidae	N, A	Flower bud, leaf, twig	3.05±0.04	4.12±0.12	2.22±0.01
11.	Hooded hopper	*Leptocentrus Taurus* (Fabricius)	Hemiptera: Membracidae	N, A		0.34±0.01	0.55±0.01	0.71±0.02
12.	Spider mites	*Tetranychus urticae* (Koch)	Acarina: Tetranychidae	N, A	Flower bud, leaf, twig	5.87±0.05	7.12±0.11	5.04±0.23
13.		*Tetranychus macfarlanei* (Baker and Pritchard)						
14.	Leaf beetle	*Madurasia obscurella* (Jacoby)	Coleoptera: Chrysomelidae	A	Leaf, young twig	1.56±0.02	3.23±0.03	2.89±0.04
15.	Flea beetle	*Altica lythri* (Aubé)		A		6.02±0.05	5.12±0.02	3.05±0.04
16.	Galerucid beetle	*Madurasia obscurella* (Jacoby)		A		2.05±0.01	3.04±0.01	1.23±0.02
17.	leaf weevil	*Blosyrus oniscus* (Ol.)	Coleoptera: Curculionidae	A	Leaf, young twig	0.76±0.01	0.89±0.02	0.67±0.01

***Damage stage*[1]: L, larva; N, nymph; A, adult**

4.2.5 Insect and mite pests of marpha (hill squash) and their rate of infestation

The rate of infestation, life stage, infested plant parts and their diversity of insect & mite pests of marpha grown in jhum fields were recorded from seedling to before harvesting fruits from farmers jhum fields at Bandarban, Rangamati and Khagrachari districts have been discussed below:

In both the years the list of insect & mite pests of marpha recorded from untreated jhum field at Bandarban, Rangamati and Khagrachari were shown in Table 4.2.5. Marpha plant serves as a host for an extensive range of insect orders. Many foliage feeding, stem feeding, fruit fly and leaf mining insect & mites belong to seven arthropod orders having 18 insect & mites species. Insects belonging to the orders Diptera, Hemiptera, Coleoptera, Lepidoptera, Thysanoptera and mites (Acarina).

Considerable insect taxa including the order of Diptera (3) on marpha crop in Jhum field which include members of dipteran families Tephritidae and Agromyzidae. Among these two families, two fruit flies species of Tephritidae (*Bactrocera cucurbitae* Coquillett and *Bactrocera dorsalis* Hendel) were frequently observed. Devastation by insect pest under Cucurbitaceae was recorded. Both fruit flies cause the maximum damage during the fruiting period and their rate of infestation were Bandarban 33.10%, Rangamati 35.37, and Khagrachari 26.57% and caused the uppermost level of infestation and considered as major insect pests. Whereas the leaf minor representing the family of Agromyzidae showed the infestation level at Bandarban 5.93%, Rangamati 6.63% and Khagrachari 6.41% and caused a moderate level of infestation by tunneling the foliage thus not cause significant loss of marpha fruit production and considered as minor insect pest.

Again the maximum insect taxa including phloem-feeders within the order of Hemiptera (4) on marpha crop in jhum field were found at all three hill districts. These include members of the hemipteran families of Aphididae, Jassidae, and Pentatomidae and these occasionally considered as the preeminent mutual sap-sucking insects' at all the three hill districts of Bangladesh during 2015-2016. Among four taxa, green stink bug had the rate of infestation of Bandarban 9.73%, Rangamati 12.91% and Khagrachari 10.32% and they caused moderate to a high level of infestation between the phloem-feeders and well-thought-out as major insect pests. Other two taxa of aphid and one of jassid showed rate of infestation of Bandarban 7.32% and 7.22%, Rangamati 7.39% and 7.14% and Khagrachari 6.01% and 6.07%, respectively having instigated moderate to low of infestation and considered as minor insect pests.

Once more only 4 insects' taxa including the foliage feeder within the order of Coleoptera which include members of Chrysomelidae and Coccinellidae families and these were sometimes referred as common insect pests' of different crops as well as other plants in the jhum field. Among them, red pumpkin beetle which badly damage at early stage of marpha plant by feeding the leaves and their mean infestation were Bandarban 14.13%, Rangamati 14.71% and Khagrachari 14.54% caused significant level of infestation and considered as major insect pests. Furthermore, the other three taxa of Coleopteran and two taxa of the mite had the rate of infestation moderate to low level and considered as minor insect and mite pests. Among the rest of 3 orders comprise 4 families including five insect taxa such as black cutworm, cucumber moth and two species of mole cricket and melon thrips which caused moderate to low infestation thus considered as minor insect pests. The tephritid fruit flies of genus *Bactrocera*, had great economic importance because they considered as key pests that most adversely affect the production and marketing of vegetables and fruits around the world (Mandal 2015, Uchôa 2012, Kumar *et al*. 2011).

4.2.6 Insect and mite pests of okra and their rate of infestation

The rate of infestation, life stage, infested plant parts and diversity of insect & mite pests of okra grown in jhum fields were recorded after okra plant arises till to before harvesting pods of okra from farmers jhum fields at Bandarban, Rangamati and Khagrachari districts have been discussed below:

In the both years the list of insect & mite pests of okra recorded from untreated jhum field at Bandarban, Rangamati and Khagrachari and reported in Table 4.2.6. Okra plant serves as a host for an extensive range of insect orders. Many foliage feeding, phloem-feeding, internal feeding and leaf mining insect & mites belong to seven arthropod orders recorded 13 insect & mites species. Insects belonging to the orders Hemiptera, Lepidoptera, Diptera, Coleoptera, and mites (Acarina) were recorded.

Considerable insect taxa including phloem-feeders within the order of Hemiptera (5 species) on okra crop in Jhum field were found at all the three hill districts. These include members of the hemipteran families of Aphididae, Cicadellidae, Aleyrodidae and Pentatomidae and these were occasionally mentioned to as the distinguished mutual sap-sucking insects' at all the three hill districts of Bangladesh during 2015-2016. Among five taxa, aphid (two species) the rate of infestation of Bandarban 26.58 %, Rangamati 30.59% and Khagrachari 29.08% which considered as the highest level. Similarly rate of infestation by jassid was observed and thus the both insects were considered as major insect pests. Other two taxa of whitefly and green sting bug found their rate of infestation were moderate to low and considered as minor insect pests. Furthermore, other five taxa okra shoot and fruit borer, leaf roller and semilooper was recorded from important insect order, Lepidoptera and covered the families of Noctuidae, Nolidae and Crambidae followed by one taxa (leaf miner) of Diptera include a family of Agromyzidae and also commonly found two taxa (spider mite) of family Tetranychidae caused moderate to low level of infestation thus considered as minor insect pests.

Results showed that, OSFB cause significant damage and recognized as a most notorious pest of okra as well as cotton boll cultivated in plne land but at jhum field very low infestation was evident at all the three hill districts due to diversified mix crops grown with the main crop rice at hill jhum.

Table 4.2.5 List of insect and mite pests of marpha in jum field and their mean percentage of infestation levels at Bandarban, Rangamati and Khagrachari during 2015 -2016

Sl. No.	Common name	Scientific name	Systematic position	Damage stage[1]	Infested plant parts	Mean % infestation (Mean±SD)		
						Bandar -ban	Ranga -mati	Khagra -chari
1.	Cucurbit fruit fly	*Bactrocera cucurbitae* (Coquillett)	Diptera: Tephritidae	L, A	Fruits	33.10±0.87	35.37±0.30	26.57±0.49
2.	Oriental fruit fly	*Bactrocera dorsalis* (Hendel)	Diptera: Tephritidae	L, A	Fruits			
3.	Red pumpkin beetle	*Raphidopalpa foveicollis* (Lucas)	Coleoptera: Chrysomelidae	L, A	Leaf	14.13±0.30	14.71±0.52	14.54±0.45
4.	Green stink bug	*Nezara viridula* (Linnaeus)	*Hemiptera*: Pentatomidae	N, A	Suck sap leaf, flower buds, flowers	9.73±0.83	12.91±0.53	10.32±0.40
5.	Aphid	*Aphis gossypii* (Glover)	*Hemiptera: Aphididae*	N, A		7.32±0.03	7.39±0.03	6.01±0.01
6.		*Myzus persicae* (Sulzer)		N, A				
7.	Jassid	*Amrasca bigutula bigutula* (Ishida).	Hemiptera: Cicadellidae	N, A		7.22±0.37	7.14±0.20	6.07±0.44
8.	Epilachna beetle	*Epilachna vigintioctopunctata* (Fab.)	Coleoptera: Coccinellidae	L, A		6.93±0.20	7.71±0.47	7.21±0.52
9.		*Epilachna dodecastigma* (Wied)		L, A	leaves			
10.	Leaf minor	*Liriomyza sativae* (Blanchard)	Diptera: Agromyzidae	L	leaves	5.93±0.03	6.63±0.04	6.41±0.02
11.	Black cutworm	*Agrotis ipsilon* (Hufnagel)	Lepidoptera: Noctuidae	L	leaves	1.05±0.01	1.11±0.01	0.93±0.02
12.	Cucumber moth	*Diaphania indica* (Saunders)	Lepidoptera: Crambidae	L	leaves	0.97±0.01	0.34±0.01	0.98±0.02
13.	Cucumber beetle	*Aulacophora indica* (Gmelin)	Coleoptera: Chrysomelidae	L, A	Flower bud, leaf, twig	2.04±0.05	3.178±0.03	2.56±0.01
14.	Mole cricket	*Gryllotalpa orientalis* (Burmeister)	Orthoptera: Gryllotalpidae	N, A	Cut and feed on root, leaf	2.09±0.01	3.11±0.03	3.56±0.05
15.		*Gryllotalpa brachyptera* (Tindale)						
16.	Melon thrips	*Thrips palmi* (Karny)	Thysanoptera: Thripidae	N, A	Leaf	4.56±0.17	3.96±0.23	5.44±0.07
17.	Spider mite	*Tetranychus truncates* (Ehara)	Acari: *Tetranychidae*	N, A	Suck sap leaf, Flower bud	6.98±0.23	7.34±0.04	3.56±0.18
18.		*Tetranychus urticae* (Kock)						

***Damage stage[1]*: L, larva; N, nymph; A, adult**

Table 4.2.6 List of insect and mite pests of lady's finger/okra in jhum field and their mean percentage of infestation levels at Bandarban, Rangamati and Khagrachari during 2015 -2016

Sl. No.	Common name	Scientific name	Systematic position	Damage stage[1]	Infested plant parts	Mean % infestation (Mean±SD)		
						Bandar -ban	Ranga -mati	Khagra -chari
1.	Aphid	*Aphis gossypii* (Glover)	*Hemiptera: Aphididae*	N, A	Suck sap leaf, Flower bud	26.58 ± 0.46	30.59±0.05	29.08±0.21
2.		*Myzus persicae* (Sulzer)						
3.	Whitefly	*Bemisia tabaci* (*Gennadius*)	Hemiptera: Aleyrodidae	N, A	Suck sap leaf, Flower bud	2.54±0.20	3.25±0.03	2.27±0.02
4.	Semilooper	*Plusia orchalcea* (Fabricius)	Lepidoptera: Noctuidae	L	Leaf	0.26±0.019	0.297±0.01	0.49±0.04
5.	Jassid	*Empoasca lybica* (*de Berg*.)	Hemiptera: Cicadellidae	N, A	Suck sap leaf, Flower bud	26.54±0.52	30.84±0.42	29.08±0.62
6.	Leaf minor	*Agromyza* sp.(Fallen)	Diptera: Agromyzidae	N, A	Leaf	2.91±0.012	1.65±0.03	2.34±0.02
7.	Okra shoot & fruit borer	*Earias vittella* (Fabricius)	Lepidoptera: Nolidae	L	Stem, Fruit	1.32±0.26	2.47±0.39	2.35±0.07
8.		*Earias insulana* (Boisduval)						
9.		*Earias fabia* (Stoll)						
10.	Leaf roller	*Haritalodes derogate* (Fabricius)	*Lepidoptera: Crambidae*	L	Leaf	1.04±0.02	1.11±0.03	2.08±0.01
11.	Spider mites	*Tetranychus macfarlanei* (Baker and Pritchard)	Acarina: Tetranychidae	N, A	Suck sap leaf, Flower bud	0.23±0.001	0.13±0.01	0.12±0.014
12.		*Tetranychus urticae* (Koch)						
13.	Green stink bug	*Nezara viridula* (Linnaeus)	*Hemiptera*: Pentatomidae	N, A	Suck sap leaf, Flower bud	1.77±0.04	1.06±0.01	2.01±0.02

***Damage stage*[1]: L, larva; N, nymph; A, adult**

4.2.7 Insect and mite pests of yard-long bean and their rate of infestation

The rate of infestation, life stage, infested plant parts and diversity of insect & mite pests of yard long bean grown in jhum fields were recorded from seedling till before harvesting pods of yard long bean from farmers jhum fields at Bandarban, Rangamati and Khagrachari districts have been discussed below:

In both the years (2015-2016) list of insect & mite pests of yard long bean recorded from untreated jhum field at Bandarban, Rangamati and Khagrachari were shown in Table 4.2.7. Yard long bean plant serves as a host for a wide range of insect orders. Many foliage feeding, pod borer, phloem-feeders, internal feeder and leaf minor insect & mites belong to seven arthropod orders recorded 16 insect & mites. Insects belonging to the orders Hemiptera, Lepidoptera, Coleoptera, Thysanoptera and mites (Acarina) were recorded.

Considerable insect taxa including phloem-feeders within the order of Hemiptera (6) on yard-long bean crop in jhum field were found at all the three hill districts. These include members of the hemipteran families of Aphididae, Jassidae, Coreidae, Cicadellidae, Membracidae, and Pentatomidae these were occasionally mentioned as the distinguished mutual sap-sucking insects' at all the three hill districts of Bangladesh during 2015-2016. Among six taxa aphid (*Aphis craccivora* Kosh*)* had the rate infestation of Bandarban 11.87%, Rangamati 10.98% and Khagrachari 12.12% and caused the highest level and measured as major insect pests. Uddin *et al*., (2014) stated the similar result and mentioned that the insect population incidence was much higher in case of aphid and pod borer.

Whereas the jassid infestation was moderate and other phloem feeders such as green sting bug, coreid bug, leafhoppers, and hooded hopper had lower rate of infestation and considered as minor insect pests. Furthermore, the other three taxa bean pod borer, greasy cutworms, and semilooper were recorded from important insect order Lepidopter and covered the families of Crambidae and Noctuidae. Among three insect taxa, bean pod borer caused the highest damage during the whole pod bearing stage in the jhum field than all other insect taxa and their mean infestation were Bandarban 12.06%, Rangamati 16.12% and Khagrachari 17.93% and thus considered as major insect pests. Although other insect pest had rate of infestation moderate to low level and considered as minor insect pests. Furthermore, four taxa (leaf beetle, galerucid beetle, flea beetle and leaf weevil) of coleopteran, two taxa of spider mites and one taxa (thrips) of Thysanoptera showed the rate of infestation at low level and categorised as minor insect and mite pests.

Table 4.2.7 List of insect & mite pests of yard long bean in jhum field and their mean percentage of infestation levels at Bandarban, Rangamati and Khagrachari during 2015 -2016

Sl. No.	Common name	Scientific name	Systematic position	Damage stage[1]	Infested plant parts	Mean % infestation (Mean±SD)		
						Bandar -ban	Ranga -mati	Khagra -chari
1.	Green jassid	*Empoasca kerri* (Pruthi)	Hemiptera: Jassidae	N, A	Suck sap Flower bud, leaf, twig	5.34±0.03	3.12±0.04	6.04±0.02
2.	Green sting bug	*Nezara viridula* (Linnaeus)	Hemiptera: Pentatomidae	N, A		3.11±0.04	2.97±0.05	2.56±0.02
3.	Coreid bug	*Leptoglossus* spp.	Hemiptera: Coreidae	N, A		3.11±0.04	2.97±0.05	2.56±0.02
4.	Aphids	*Aphis craccivora* (Kosh)	Hemiptera: Aphididae	N, A	Suck sap Flower bud, leaf, twig	11.87±0.23	10.98±0.11	12.12±0.03
5.	Thrips	*Megalurothrips distalis* (Karny)	Thysanoptera: Thripidae	N, A		2.67±0.01	3.11±0.02	1.23±0.01
6.	Bean pod borer	*Maruca testulalis* (Geyer)	Lepidoptera: Crambidae	L	Flower bud, pod	12.06±0.04	16.12±0.05	17.93±0.12
7.	Greasy cutworms	*Agrotis ipsilon* (Hufnagel)	Lepidoptera: Noctuidae	L	Leaf, Flower bud	5.91±0.14	6.01±0.45	4.01±0.02
8.	Semilooper	*Diachrysia* spp.	Lepidoptera: Noctuidae	L	Leaf	0.78±0.02	0.67±0.03	0.89±0.01
9.	Leafhoppers	*Empoasca* spp.	Hemiptera: Cicadellidae	N, A	Suck sap Flower bud, leaf, twig	2.15±0.03	2.72±0.11	2.10±0.01
10.	Hooded hopper	*Leptocentrus Taurus* (Fabricius)	Hemiptera: Membracidae	N, A		0.55±0.02	0.32±0.01	0.29±0.03
11.	Spider mites	*Tetranychus urticae* (Koch)	Acarina: Tetranychidae	N, A		3.97±0.02	4.03±0.01	5.11±0.05
12.	Spider mites	*Tetranychus macfarlanei* (Baker and Pritchard)	Acarina: Tetranychidae	N, A		3.97±0.02	4.03±0.01	5.11±0.05
13.	Leaf beetle	*Madurasia obscurella* (Jacoby)	Coleoptera: Chrysomelidae	A	Leaf	1.67±0.01	2.07±0.02	1.05±0.01
14.	Galerucid beetle	*Madurasia obscurella* (Jacoby)	Coleoptera: Chrysomelidae	A	Leaf, young twig	1.67±0.01	2.07±0.02	1.05±0.01
15.	Flea beetle	*Altica lythri* (Aubé)	Coleoptera: Chrysomelidae	A		1.67±0.01	2.07±0.02	1.05±0.01
16.	Leaf weevil	*Blosyrus oniscus* (Olivier)	Coleoptera: Curculionidae	A		1.67±0.01	2.07±0.02	1.05±0.01

***Damage stage*[1]: L, larva; N, nymph; A, adult**

4.2.8 Insect and mite pests of roselle and their rate of infestation

The rate of infestation, life stage, infested plant parts and diversity of insect & mite pests of roselle grown in jhum fields were recorded from seedling to before harvesting fruits from farmers jhum fields at Bandarban, Rangamati and Khagrachari districts have been discussed below:

In both the years the list of insect & mite pests of roselle recorded from untreated jhum field at Bandarban, Rangamati and Khagrachari was shown in (Table 4.2.8). Roselle plant serves as a host for a petite range of insect orders. Certain bollworm, phloem-feeders, and internal feeder belong to only two arthropod orders recorded 6 insect species. Insects belonging to the orders Hemiptera and Lepidoptera among them, phloem-feeders were the dominant taxa whereas one taxa representing the later order in jhum field were found at all the three hill districts.

Maximum five insect taxa including phloem-feeders include members of the hemipteran families of Aphididae, Pyrrhocoridae, Aleurodidae, Cicadellidae, and Pseudococcidae and these were sporadically mentioned to as the distinguished mutual sap-sucking insects' at all the three hill districts of Bangladesh during 2015-2016. Among five taxa red cotton stainer (*Dysdercus cingulatus* Fabricious) caused mean infestation of Bandarban 4.98%, Rangamati 5.045% and Khagrachari 7.012% responsible for the highest level of infestation and measured as major insect pests among the phloem-feeders.

Whereas other hemipteran insect taxa such as pink hibiscus mealybug, aphid, whitefly and leafhoppers had the infestation rate low level and considered as minor insect pests. Furthermore, this red cotton stainer was recorded from important insect order Lepidoptera which include a family of Nolidae caused very stumpy damage during the whole pod bearing season in the jhum field and its mean infestation were Bandarban 1.02%, Rangamati 0.934% and Khagrachari 2.12% and thus considered as minor insect pests.

Table 4.2.8 List of insect & mite pests of roselle in jhum field and their mean percentage of infestation levels at Bandarban, Rangamati and Khagrachari during 2015 -2016

Sl. No.	Common name	Scientific name	Systematic position	Damage stage[1]	Infested plant parts	Mean % infestation (Mean±SD)		
						Bandar -ban	Ranga -mati	Khagra -chari
1.	Pink hibiscus mealybug	*Maconellicoccus hirsutus* (Green)	Hemiptera: Pseudococcidae	N, A	Suck sap Flower bud, leaf, young twig	4.02±0.04	3.12±0.02	2.98±0.03
2.	Aphid	*Aphis gossypii* (Glover)	Hemiptera: Aphididae	N, A	Suck sap Flower bud, leaf, young twig	3.11±0.07	2.31±0.02	1.80±0.01
3.	Whitefly	*Bemisia tabaci* (Genn.)	Hemiptera: Aleurodidae	N, A	Suck sap Flower bud, leaf, young twig	1.08±0.02	2.07±0.05	0.99±0.01
4.	Red cotton stainer	*Dysdercus cingulatus* (Fabricius)	Hemiptera: *Pyrrhocoridae*	N, A	Suck sap young boll, leaf, young twig	4.98±0.03	5.05±0.01	7.01±0.05
5.	Cotton spotted bollworm	*Earias insulana* (Boisd.)	Lepidoptera : Nolidae	L	Bud, fruit	1.02±0.01	0.93±0.02	2.12±0.02
6.	Leafhopper	*Empoasca* spp.	Hemiptera: Cicadellidae	N, A	Suck sap young boll, leaf, young twig	2.87±0.04	2.06±0.05	1.67±0.01

***Damage stage*[1]: L, larva; N, nymph; A, adult**

4.2.9 Insect and mite pests of brinjal and their rate of infestation

The rate of infestation, life stage, infested plant parts and diversity of insect & mite pests of brinjal grown in jhum fields were recorded from seedling till to harvesting brinjal fruits from farmer's jhum fields at Bandarban, Rangamati and Khagrachari districts have been discussed below:

In both the years (2015-2016) the list of insect & mite pests of brinjal recorded from untreated jhum field at Bandarban, Rangamati and Khagrachari was shown in Table 4.2.9. Brinjal plant serves as a host for an extensive range of insect orders. Many foliage feeding, shoot and fruit borer, phloem-feeders insect and mites belong to six arthropod orders recorded 24 insect & mites species. Insects belonging to the orders Lepidoptera, Hemiptera, Orthoptera, Coleoptera, Thysanoptera and mites (Acarina) were recorded.

Considerable insect taxa including the order of Lepidoptera (6) infesting brinjal crop in jhum field which include members of lepidopteran families of Crambidae and Noctuidae are frequently observed and found as devastating insect pest of in the brinjal. Brinjal shoot and fruit borer caused maximum damage during the fruiting period and their rate of infestation were Bandarban 32.17%, Rangamati 35.98% and Khagrachari 29.37% showing the uppermost level of infestation and considered as major insect pests. Sultana *et al*. (2018) and Kumar *et al*., 2010 reported similar results and found the minimum shoot infestation was found in BARI begun-6 (29.60%, 32.40%, 29.86% and 29.38%, respectively at four different stages of eggplant).

Whereas 3 insects of foliage caterpillar (cotton leaf worm, cabbage caterpillar and cutworm) representing the family of Noctuidae showed the infestation rate of Bandarban 20.12%, Rangamati 25.09% and Khagrachari 18.89% which caused the second uppermost level of infestation and considered as major insect pests. Rest 2 taxa of leaf roller caused moderate infestation at all the three hill districts experimental jhum fields of Bangladesh and considered as minor insect pests.

Phloem-feeders within the order of Hemiptera (8) attacking brinjal crop in jhum field were found at all the three hill districts. These include members of the hemipteran families as of Aphididae, Aleurodidae, Margarodidae, Pentatomidae, Tingidae, Jassidae, Pseudococcidae and Cicadellidae and these were occasionally mentioned as the preeminent mutual sap-sucking insects' at all the three hill districts of Bangladesh during (2015-2016). Among eight taxa (aphid, whitefly, scale insect, shield bug, lace bug, green jassid, pink mealybug and jassid of brinjal) initiated moderate to low level of infestation between the phloem-feeders and considered as minor insect pests.

Once more only 3 insect taxa including the foliage feeder within the order of Coleoptera which include members of Chrysomelidae and Coccinellidae these were sometimes referred as common insect pests infesting different crops as well as other plants in the jhum field. Among them, two species (Epilachna beetle) badly damage at early stage of brinjal plant by feeding the leaves and their rate of infestation were Bandarban 12.56%, Rangamati 14.07% and Khagrachari 10.56% and caused a significant level of infestation and considered as major insect pests. Furthermore, other one taxa (flea beetle) of coleopteran and two taxa of spider mites showed mean percentage of infestation at moderate to low level and considered as minor insect and mite pests.

Among the rest of different 2 orders i.e., (Orthoptera and Thysanoptera) comprise 4 families Tetrigidae, Acrididae, Grylloidea and Tettigoniidae including four insect taxa such as pygmy grasshoppers, green grasshopper, field cricket and bush crickets or katydids showed low infestation at all experimental jhum fields thus considered as minor insect and pests. Whereas one taxa of Thysanoptera i.e., thrips also showed infestation low level and thus considered as minor insect pests. Flower bud, flower and fruits or pod stage of jhum crop were infested by thrips thus need to care about their hosts and bio-ecology as promising insect pests. Ghosh *et al*. (2012), Khorsheduzzaman *et al*. (2010), Bharadiya and Patel (2005) and Nayar *et al*. (1986) reported that jassid, *Amrasca biguttula biguttula* (Ishida); aphid, *Aphis gossypii* (Glover); whitefly, *Bemisia tabaci* (Genn.); and shoot and fruit borer, *Leucinodes orbonalis* (Guen.); were identified as the major pests of brinjal.

Bharadiya and Patel (2005) observed 28 species of insect pests under seven different insect orders from the brinjal ecosystem where 53 species of insect pests of brinjal. Among the pests, major sucking pests like whitefly, jassid, aphid and thrips are big threats to brinjal growers which attack right from nursery stage till harvesting (Regupathy *et al*. 1997).

Table 4.2.9 List of insect & mite pests of brinjal in jhum field and their rate of infestation levels at Bandarban, Rangamati and Khagrachari during 2015 -2016

Sl. No.	Common name	Scientific name	Systematic position	Damage stage[1]	Infested plant parts	Mean % infestation (Mean±SD)		
						Bandar -ban	Ranga -mati	Khagra -chari
1.	Brinjal shoot and fruit borer	*Leucinodes orbonalis* (Guenée)	Lepidoptera: Crambidae	L	Leaf, young twig, fruit	32.17±1.78	35.98±1.67	29.37±2.87
2.	Leaf roller	*Eublemma olivacea* (Walker)	Lepidoptera: Noctuidae	L	Leaf	8.44±0.45	7.97±0.23	6.45±0.09
3.		*Sylepta derogata* (Fabricius)	Lepidoptera: Crambidae	L				
4.	Cotton leaf worm	*Spodoptera litura* (Fabricius)	Lepidoptera: Noctuidae	L	Leaf	20.12±0.23	25.09±0.34	18.89±0.16
5.	Cabbage caterpillar	*Helicoverpa armigera* (Hübner)	Lepidoptera: Noctuidae	L	Leaf			
6.	Cut worm	*Agrotis* spp.	Lepidoptera: Noctuidae	L	Leaf			
7.	Spider mite	*Tetranychus urticae* (Koch)	Acarina: Tetranychidae	N, A	Suck sap Flower bud, leaf, twig	4.98±0.05	6.12±0.03	3.98±0.02
8.		*Tetranychus macfarlanei* (Baker and Pritchard)		N, A				
9.	Aphid	*Aphis gossypii* (Glover)	Hemiptera: Aphididae	N, A		7.09±0.03	5.84±0.07	10.45±0.11
10.	Whitefly	*Bemisia tabaci* (Gennadiu)	Hemiptera: Aleurodidae	N, A	Suck sap Flower bud, leaf, twig	5.77±0.02	6.43±0.01	6.11±0.01
11.	Scale insect	*Aulacaspis* spp.	Hemiptera: Margarodidae	N, A		1.09±0.01	1.11±0.04	2.03±0.01

Contd…

Table 4.2.9 (Contd.)

Sl. No.	Common name	Scientific name	Systematic position	Damage stage[1]	Infested plant parts	Mean % infestation (Mean±SD)		
						Bandar-ban	Ranga-mati	Khagra-chari
12.	Shield bug	*Eysarcoris ventralis* (Westwood)	Hemiptera: Pentatomidae	N, A	Suck sap Flower bud, leaf, twig	0.98±0.02	0.77±0.02	0.69±0.03
13.	Lace bug	*Gargaphia solani* (Heidemann)	Hemiptera: Tingidae	N, A				
14.	Green jassid	*Empoasca kerri* (Pruthi)	Hemiptera: Jassidae	N, A	Suck sap Flower bud, leaf, twig	4.23±0.03	3.87±0.01	4.11±0.02
15.	Jassid of brinjal	*Amrasca biguttula biguttula* (Ishida)	Hemiptera: Cicadellidae	N, A				
16.	Pink mealybug	*Phenacoccus hirsutus* (Green)	Hemiptera: Pseudococcidae	N, A	Suck sap Flower bud, leaf, twig	3.07±0.01	1.45±0.02	2.94±0.01
17.	Flea beetle	*Altica lythri* (Aubé)	Coleoptera: Chrysomelidae	A	Leaf, young twig	3.45±0.17	3.11±0.09	5.67±0.05
18.	Thrips	*Megalurothrips distalis* (Karny)	Thysanoptera: Thripidae	N, A	Leaf	3.08±0.03	4.02±0.02	4.11±0.01
19.	Epilachna beetle	*Epilachna vigintioctopunctata* (Fabricius)	Coleoptera: Coccinellidae	A	Flower bud, leaf, young twig	12.56±0.06	14.07±0.02	10.6±0.03
20.		*E. dodecastigma* (Wied)		A				
21.	Pygmy grasshoppers	*Paratettix* spp.	Orthoptera: Tetrigidae	N, A	Leaf	2.78±0.11	3.23±0.08	2.11±0.04
22.	Green grasshopper	*Atractomorpha crenulata* (Fab.)	Orthoptera: Acrididae	N, A	Leaf			
23.	Field cricket	*Brachytrypes portentosus* (Lichtenstein)	Orthoptera: Grylloidea	N, A	Leaf	3.96±0.08	5.45±0.05	3.93±0.04
24.	Bush crickets/ katydids	*Conocephalus longipennis* (Haan)	Orthoptera: Tettigoniidae	N, A	Leaf			

***Damage stage*[1]: L, larva; N, nymph; A, adult**

4.2.10 Insect and mite pests of chili (bindu morich) and their rate of infestation

Percent of infestation, life stage, infested plant parts and diversity of insect & mite pests of chili grown in jhum fields were recorded at chili seedling till before harvesting of fruit from farmer's jhum fields at Bandarban, Rangamati and Khagrachari districts have been discussed below:

During both years the list of insect & mite pests of chili recorded from untreated jhum field at Bandarban, Rangamati and Khagrachari has been shown in (Table 4.2.10). Chili plant serves as a host for a moderate range of insect orders. Many foliage feeding, thrips, fruit borer or gram caterpillar, phloem-feeders insect and mites belong to six arthropod orders recorded 11 insect & mites species. Insects belonging to the orders Hemiptera, Lepidoptera, Coleoptera, Isoptera, Thysanoptera and mites (Acarina). Only two insect taxa including the order of Lepidoptera attacking chili crop in jhum field which include members of lepidopteran family Noctuidae are observed and found devastating insect pest on chili plant. Among the 2 taxa chili fruit borer or gram caterpillar caused maximum damage during the fruiting period and their mean infestation were Bandarban 6.07%, Rangamati 5.93% and Khagrachari 5.77% which were moderate level whereas ragi cutworm infestation level was low thus both considered as minor insect pests.

Again maximum 5 insect taxa including phloem-feeders within the order of Hemiptera on chili crop in jhum field were found at all the three hill districts. These include members of the Hemipteran families, Aphididae, Aleurodidae, Pseudococcidae and Cicadellidae those were occasionally mentioned as the well-known mutual sap-sucking insects' at all the three hill districts of Bangladesh during 2015-2016. Among five taxa (aphid, whitefly, jassid and mealybug) showed moderate to low level of infestation between the phloem-feeders and well-thought-out as minor insect pests.

Only one mite taxa commonly known as broad mite (*Polyphagotarsonemus latus* Banks) found as tender leaf sucker within the order of Acarina which include a member of Tarsonemidae that tiny mite pests are not seen by necked eye and in Bangladesh well known as a white or yellow mite of jute as well as a common pest of chili and other ornamental plants. Among the different insect & mite taxa broad mite badly damage throughout jhum season of chili plant and their rate of infestation were Bandarban 25.82%, Rangamati 16.06% and Khagrachari 23.34% caused the uppermost level of infestation and considered as major mite pests. Furthermore other one taxa rasping and sucking (thrips) of order Thysanopteran include Thripidae family revealed their rate of infestation as Bandarban 15.03%, Rangamati 17.84% and Khagrachari 21.17% showed the second highest infestation and considered as major insect pest. Among the jhum crops different stage such as flower bud, flower and fruits or pod were infested by thrips thus need to care about their hosts and bio-ecology as promising insect pests. Rest 2 taxa of order Isoptera which include a member of family

Termitidae infest root and stem triggered very insufficient infestation at all the three hill districts experimental jhum fields of Bangladesh and considered as minor insect pests.

Table 4.2.10 List of insect & mite pests of chili *(Bindu morich)* in jhum field and their rate of infestation levels at Bandarban, Khagrachari and Khagrachari during 2015-2016

Sl. No.	Common name	Scientific name	Systematic position	Damage stage[1]	Infested plant parts	Mean % infestation (Mean±SD)		
						Bandar-ban	Ranga-mati	Khagra-chari
1.	Chili Fruit borer/Gram caterpillar	*Helicoverpa armigera* (Hübner)	Lepidoptera: *Noctuidae*	L	feeds flower buds, flowers, boor fruits	6.07±0.05	5.93±0.07	5.77±0.01
2.	Broad Mite	*Polyphagotarsonemus latus* (Bank)	Acari: Tarsonemidae	N, A	Suck sap leaf, flower buds, flowers	25.82±0.03	16.06±0.04	23.34±0.01
3.	Aphid	*Aphis gossypii* (Glover)	*Hemiptera: Aphididae*	N, A		3.5±0.09	3.39±0.02	4.10±0.03
4.		*Myzus persicae* (Sulzer)		N, A				
5.	Thrips	*Scirtothrips dorsalis* (Hood)	Thysanoptera: Thripidae	N, A	Suck sap leaf, flower buds, flowers	15.03±0.12	17.84±0.56	21.17±0.81
6.	Jassid	*Amrasca bigutula bigutula* (Ishida).	Hemiptera: Cicadellidae	N, A		1.06±0.03	1.11±0.04	1.04±0.06
7.	Mealybug	*Maconellicoccus hirsutus* (Green)	Hemiptera: Pseudococcidae	N, A	Stem, leaf, twig, bud	2.07±0.04	3.42±0.22	3.045±0.02
8.	Termite	*Nephotettix nigropictus* (Stal)	Isoptera: Termitidae	N, A	cut and feed on root	0.67±0.01	0.82±0.01	1.91±0.04
9.		*Odontotermes brunneus* (Hagen)		N, A				
10.	Whitefly	*Bemisia tabaci* (Gennadius)	Hemiptera: Aleyrodidae	N, A	Suck sap leaf, flower buds, flowers	5.02±0.13	7.01±0.03	3.76±0.02
11.	Ragi cutworm	*Spodoptera litura* (Fabricius)	Lepidoptera: Noctuidae	L	cut and feed on leaves	2.56±0.12	4.02±0.05	3.09±0.02

***Damage stage[1]*: L, larva; N, nymph; A, adult**

4.2.11 Insect and mite pests of maize and their rate of infestation

Percent of infestation, life stage, infested plant parts and diversity of insect & mite pests of maize grown in jhum fields were recorded from seedling till before harvesting of maize cob from farmers jhum fields at Bandarban, Rangamati and Khagrachari districts have been discussed below:

In the year 2015 & 2016 the list of insect mite pests of maize recorded from untreated jhum field at Bandarban, Rangamati and Khagrachari was shown in Table 4.2.11. Maize plant serves as a host for an extensive range of insect orders. Many foliage feeder, corn earworm, borer, phloem-feeders and Termite belong to six arthropod orders recorded 12 insect belonging to orders Hemiptera, Lepidoptera, Coleoptera, Isoptera and Orthoptera.

Maximum 4 insect taxa of different grasshopper were recorded from important insect order. Orthoptera comprise the only family of Acrididae represented are particularly foliage feeder on maize plant at jhum field and caused maximum damage during the vegetative period and their rate of infestation were Bandarban 67.71%, Rangamati 65.07% and Khagrachari 74.44% which showed the uppermost level thus their combined destruction considered as major insect pests.

Again the second highest (3) insect taxa of Lepidoptera encompass families of Noctuidae and Pyralidae such were common armyworm, maize stem borer and corn earworm found in the experimental jhum fields at all three hill districts as well as in the maize fields in the valley. During the experimental period, these lepidopteran pest mainly attacked on leaves, stem and cob and their rate of infestation were at low levels thus considered as minor insect pests.

Once more only the two insect taxa including phloem-feeders within the order of Hemiptera on maize crop in jhum field were found at early stage of the crop and further infestation occurs during the later stage of the crop. These include aphid member of the Hemipteran family Aphididae and these were known as mutual sap-sucker followed by Coleopteran order one taxa (leaf beetle), family Chrysomelidae triggered an insignificant level of damage and considered as minor insect pests. Rest order, Isoptera only two taxa of termite represented the family Termitidae showed similar trend i.e., low level of the rate of infestation thus reflected as minor insect pests. The tribal people are much familiar with sweet maize cultivation as it was their one of the main food crop in the hill. From the survey from different jhumian people and found that they are very anxious about fox attack on maize field and different cob eating birds caused economic damage which was normal feature in jhum field in the hill district.

Table 4.2.11 List of insect and mite pests of maize in jhum field and their rate of infestation levels at Bandarban, Rangamati and Khagrachari during 2015 -2016

Sl. No.	Common name	Scientific name	Systematic position	Damage stage[1]	Infested plant parts	Mean % infestation (Mean±SD)		
						Bandar-ban	Ranga-mati	Khagra-chari
1.	Termite	*Nephotettix nigropictus* (Stal)	Isoptera: Termitidae	N, A	Cut and feed on root	3.18±0.21	2.67±0.05	5.27±0.25
2.		*Odontotermes brunneus* (Hagen)		N, A				
3.	Grasshopper	*Oxya velox* (Fabricius)	Orthoptera: Acrididae	N, A	Feed on leaves	67.71±0.46	65.07±0.48	74.44±0.27
4.		*Oxya chinensis* (Tunaberg)						
5.		*Hieroglyphus banian* (Fabricius)						
6.		*Hieroglyphus bettoni* (Kirby)						
7.	Common armyworm	*Spodoptera litura* (Fabricius)	Lepidoptera: Noctuidae	L	Cut and feed on leaves	3.78±0.34	4.23±0.24	2.67±0.11
8.	Corn earworm	*Helicoverpa zea* (Boddie)	Lepidoptera: Noctuidae	L	Cob and Leaf	3.02±0.03	4.11±0.20	5.08±0.11
9.	Maize stem borer	*Sesamia inferens* (Francis Walker)	Lepidoptera: Pyralidae	L	Stem	2.45±0.03	4.34±0.22	2.87±0.06
10.	Aphid	*Aphis gossypii* (Glover)	*Hemiptera: Aphididae*	N, A	Suck sap leaf, flower buds, flowers	5.85±0.09	6.31±0.02	3.15±0.03
11.		*Myzus persicae* (Sulzer)						
12.	Leaf beetle	*Monolepta signata* (Oliv.)	Coleoptera: Chrysomelidae	A	Flower bud, leaf, twig	5.18±0.045	6.21±0.04	4.22±0.045

***Damage stage*[1]: L, larva; N, nymph; A, adult**

4.2.12 Insect and mite pests of cotton and their rate of infestation

Percent infestation, life stage, infested plant parts and diversity of insect & mite pests of cotton grown in jhum fields were recorded seedling till before harvesting pods of cotton from farmers jhum fields at Bandarban, Rangamati and Khagrachari districts have been discussed below:

The list of insect & mite pests of cotton recorded from untreated jhum field at Bandarban, Rangamati and Khagrachari was presented in Table 4.2.12. The cotton plant serves as a host for an extensive range of insect orders. Many foliage feeding, stem feeding, fruit fly and leaf mining insect & mites belong to seven arthropod orders recorded 45 texa of insect & mites. Insects belonging to the orders Orthoptera, Lepidoptera, Hemiptera, Coleoptera, Isoptera and mites (Acarina). Fifteen insect taxa including the order of Orthoptera on cotton crop in rice-cotton intercrop field which include members of Orthopteran families of Acrididae and Gryllidae.

Among these two families, 14 insect taxa such as different grasshopper and migratory locust represented the family of Acrididae are frequently observed in the hill jhum field and foliage feeder at vegetative stage and their combined infestation were Bandarban 5.28%, Rangamati 19.04% and Khagrachari 5.47% caused a moderate level whereas at Rangamati infestation was comparatively higher than other two hills experimental field and considered as major insect pests as they have the potentiality to damage significantly level. However, field cricket representing the family of Gryllidae and its rate of infestation were Bandarban 3.05%, Rangamati 4.12% and Khagrachari 4.12% and caused moderate to a low level as foliage feeder resulting in significant loss of cotton leaves and thus considered as minor insect pest.

Second maximum (13) insect taxa including the foliage as well as internal feeder within the order of Lepidoptera which include members of the families of Nolidae, Noctuidae, Crambidae, Gelechidae, Pyralidae and Arctiidae referred as communal insect pests. Among the 6 families 13 insect taxa such as spotted bollworm, American bollworm, pink bollworm, leaf roller, black cutworm, hairy caterpillar and armyworm caused percent infestation of very low level during 2015-2016 at all the three hill district. Whereas only 3 infesting insect taxa such as leaf beetle, black weevil and grey weevil represented the order of Coleoptera which include families of Chrysomelidae and Curculionidae, as well as 2 texa of spider mite, were considered as minor insect & mite pests as their infestation level were moderate to low.

Ten insect taxa including phloem-feeders within the order of Hemiptera on cotton crop in rice-cotton intercrop field were found at all the three hill districts. These include members of the hemipteran families of Aphididae, Aleyrodidae, Cicadellidae, Pseudococcidae, Pyrrhocoridae and Pentatomidae and these were infrequently considered as the distinguished mutual sap-sucking insects' at all the three hill districts of Bangladesh during 2015-2016.

Among ten insect's taxa two species of aphid caused the infestation rate of 15.67% at Bandarban, 22.45% at Rangamati and 19.67% at Khagrachari, whereas jassid and Indian cotton jassid caused the infestation rate of 16.45% at Bandarban, 18.05% at Rangamati and 19.03% at Khagrachari. Another sucking insect i.e., whitefly has similar trend of percent of infestation and were Bandarban 9.77%, Rangamati 23.13% and Khagrachari 6.76% and these phloem-feeders caused moderate to high level of infestation and considered as major insect pests. Rest of five insect taxa including spiralling whitefly, pink mealybug, tailed mealybug, red cotton bug and green stink bug caused moderate to low level of infestation and considered as minor insect pests.

Furthermore, other two taxa of termite in the order of Isoptera, representing family Termitidae and their rate of infestation were Bandarban 0.25%, Rangamati 1.46% and Khagrachari 1.52% showing very low level of infestation at early stage of the cotton crop and considered as minor insect pests.

Table 4.2.12 List of insect & mite pests of cotton and their rate of infestation levels at rice- cotton intercrop at Bandarban, Rangamati and Khagrachari during 2015-2016

Sl. No.	Common name	Scientific name	Systematic position	Damage stage[1]	Infested plant parts	Mean % infestation (Mean±SD)		
						Bandar-ban	Ranga-mati	Khagra-chari
1.	Spotted bollworm	*Earias vittella*.(Fabricius)	Lepidoptera: Nolidae	L	Flower bud, boll	0.37±0.01	2.41±0.12	0.33±0.01
2.		*Earias insulana* (Boisduval)		L				
3.		*Earias fabia* (Stoll)		L				
4.	American bollworm	*Helicoverpa armigera* (Hubner)	Lepidoptera: Noctuidae	L	Flower bud, boll			
5.	Pink bollworm	*Pectinophora gossypiella* (Saunders)	Lepidoptera: Gelechidae	L	Flower bud, boll			
6.	Whitefly	*Bemisia tabaci* (Gennadius)	*Hemiptera:* Aleyrodidae	N, A	Leaf, Flower bud	9.77±0.05	23.13±0.23	6.76±0.12
7.	Spiraling whitefly	*Aleurodicus dispersus* (Russell)		N, A	Leaf	0.52±0.01	1.03±0.02	0.31±0.01
8.	Aphid	*Aphis gossypii* (Glover)	*Hemiptera: Aphididae*	N, A	Flower bud, leaf, twig	15.67±0.56	22.45±0.23	19.67±0.06
9.		*Myzys persicae* (Sulzer)		N, A				
10.	Semilooper	*Plusia orchalcea* (Fab.)	Lepidoptera: Noctuidae	L	Leaf	0.21±0.02	0.19±0.01	0.31±0.043
11.	Cotton semilooper	*Tarache notabilis* (Walker)		L	Leaf			
12.	Green semilooper	*Anomis flava* (Fabricius)		L	Leaf			
13.	Jassid	*Empoasca lybica* (de Berg.)	Hemiptera: Cicadellidae	N, A	Flower bud, leaf, twig	16.45±0.32	18.05±0.56	19.03±0.03
14.	Indian cotton jassid	*Amrasca biguttula biguttula* (Ishida)		N, A	Flower bud, leaf, twig			
15.	Black weevil	*Cyrtozemia cognata* (Marshall)	Coleoptera: Curculionidae	A	Flower bud, leaf, twig	0.34±0.02	0.87±0.01	0.93±0.02
16.	Grey weevil	*Myllocerus maculosus* (Desb.)		A	Flower bud, leaf, twig			

Damage stage*[1]: L, larva; N, nymph; A, adult** ***Contd…

Table 4.2.12 (Contd.)

Sl. No.	Common name	Scientific name	Systematic position	Damage stage[1]	Infested plant parts	Mean % infestation (Mean±SD)		
						Bandar-ban	Ranga-mati	Khagra-chari
17.	Indian grasshopper	*Acrida exaltata* (Walker)	Orthoptera: Acrididae	N, A	Leaf	5.28±0.03	19.04±0.33	5.47±0.51
18.	Grasshopper	*Oxya velox* (Fabricius)		N, A	Leaf			
19.		*Oxya chinensis* (Tunaberg)		N, A	Leaf			
20.		*Hieroglyphus banian* (Fabricius)	Orthoptera: Acrididae	N, A	Leaf			
21.		*Hieroglyphus bettoni* (Kirby)		N, A	Leaf			
22.	Tobacco grasshopper	*Atractomorpha crenulata* (Fabricius)		N, A	Leaf			
23.	Grasshopper / migratory locust	*Locusta migratoria manilensis* (Meyen)	Orthoptera: Acrididae	N, A	Leaf			
24.	Grasshopper	*Trilophidia annulata (*Thunberg)		N, A	Leaf			
25.		*Oedaleus abruptus* (Thunberg)		N, A	Leaf			
26.		*Aiolopus simulatrix* (Walker)	Orthoptera: Acrididae	N, A	Leaf			
27.		*Aiolopus thalassinus thalassinus* (Fabricius)		N, A	Leaf			
28.		*Truxalis viridifasciata* (Krauss)		N, A	Leaf			
29.		*Oxya japonica* *Japonica* (Thunberg)	Orthoptera: Acrididae	N, A	Leaf			
30.		*Spathosternum prasiniferum prasiniferum* (Walker)		N, A	Leaf			
31.	Leaf beetle	*Lilioceris lilii* (Scopoli)	Coleoptera: Chrysomelidae	A	Leaf	3.21±0.02	3.20±0.02	4.02±0.11
32.	Spider mites	*Tetranychus macfarlanei* (Baker and Pritchard)	Acarina: Tetranychidae	N, A	Suck sap leaf, Flower bud	0.43±0.03	0.33±0.02	0.21±0.03
33.		*Tetranychus urticae* (Koch)						

***Damage stage*[1]: L, larva; N, nymph; A, adult** *Contd…*

Table 4.2.12 (Contd.)

Sl. No.	Common name	Scientific name	Systematic position	Damage stage[1]	Infested plant parts	Mean % infestation (Mean±SD)		
						Bandar -ban	Ranga -mati	Khagra -chari
34.	Field cricket	*Brachytrupes portentosus* (Lichtenstein)	Orthoptera: Gryllidae	N, A	Leaf	3.05±0.23	4.12±0.12	4.12±0.10
35.	Termite	*Odontotermes obesus* (Rambur)	Isoptera: Termitidae	N, A	feed root and stem	0.25±0.01	1.46±0.02	1.52±0.01
36.		*Microtermes obesi* (Holmgren)		N, A				
37.	Pink mealybug	*Phenacoccus hirsutus* (Green)	Hemiptera: Pseudococcidae	N, A	Suck sap Flower bud, leaf, twig	4.01±0.02	3.41±0.11	3.05±0.021
38.	Tailed mealybug	*Ferrisiana virgata* (Cockerell)		N, A				
39.	Red cotton bug	*Dysdercus cingulatus* (Fabricius)	Hemiptera: Pyrrhocoridae	N, A	Suck sap Flower bud, leaf, young twig, boll	4.11±0.03	7.81±0.87	5.15±0.04
40.	Green stink bug	*Nezara viridula* (Linnaeus)	Hemiptera: Pentatomidae	N, A	Suck sap Flower bud, leaf, young twig,	4.19±0.33	2.39±0.12	2.78±0.11
41.	Leaf roller	*Sylepta derogata* (Fabricius)	Lepidoptera: Crambidae	L	Leaf	4.63±0.07	3.21±0.02	2.59±0.01
42.	Leaf roller	*Haritalodes derogata* (Fabricius)		L				
43.	Black cutworm	*Agrotis ipsilon* (Hufnagel)	Lepidoptera: Pyralidae	L	Leaf	1.07±0.06	2.24±0.01	1.71±0.04
44.	Hairy caterpillar	*Spilarctia obliqua* (Walker)	Lepidoptera: Arctiidae	L	Leaf	0.67±0.022	1.50±0.11	0.67±0.11
45.	Armyworm	*Spodoptera litura* (Fabricius)	Lepidoptera: Noctuidae	L	Leaf	0.45±0.01	0.12±0.01	0.87±0.01

***Damage stage*[1]: L, larva; N, nymph; A, adult**

4.3 Experiment 3. Population dynamics and extent of damage of major insect pests found in jhum and rice-cotton intercropping system

The experiment was conducted in the farmer's field at hill districts of Bandarban, Rangamati and Khagrachari from 2015 to 2016. The main target of the experiment was to study the dynamics of insect pests for the hilly regions of Bangladesh and to determine the extent of damage caused by the different insect & mite pests of jhum and cotton-rice intercrop.

4.3.1 Population dynamics and extent of damage of major insect pests found in jhum system

The insect & mite pests of jhum field such as rice, maize, chili, marpha, lady's finger (okra), sesame, country bean, yard long bean, cowpea, brinjal and roselle and their dynamics of the population as well as infestation were studied and the results have been discussed and interpreted in this section below under the following sub-headings:

4.3.1.1 Population dynamics of aphid of chili in jhum field

During the year 2015, population levels of aphid attacking chili at Bandarban, Rangamati and Khagrachari are shown in Figure 4.3.1.1 (a, b and c). Figures revealed that aphid infestation started at the early stage of chili plant emerge from the jhum field with a number of aphid leaf^{-1} were 0.26, 0.22 and 0.33 at Bandarban, Rangamati and Khagrachari, respectively during early week of May.

Then the number of aphid leaf^{-1} were gradually increased in the first week of June with increased relative humidity and rainfall at three hill districts. With increasing of rainfall and temperature, the population of aphid leaf^{-1} suddenly decreased up to 1st week of July and slightly increased, and remain more or less fixed number up to 1st week of August at all experimental regions of hilly districts. With the decreasing of rainfall, the population of aphid leaf^{-1} increased gradually and reached a peak on 3rd week of September at Bandarban (0.72) and Khagrachari (0.87) in both experimental fields whereas, at Rangamati the highest number of aphid leaf^{-1} (0.72) was observed at the end of the 3rd week of August and then slightly declined the population and again reached the 2nd highest peak on 3rd week of September.

Successively again the population decreased with the decreasing of abiotic factors at all experimental field of the three hill region of Bangladesh, and one more time increased at the later stage of the crop growth when the temperature decreased with no rainfall. The trend of the mean number of aphid leaf^{-1} during 2015 was linear at all experimental jhum field of Bandarban, Rangamati and Khagrachari. Aphids are an example of a 'stealthy' pest, in contrast to chewing herbivores, which macerate plant tissue, they are adapted to feed on phloem sap (Goggin 2007). The amount of phloem sap an individual aphid can consume during its relatively short lifetime is small compared to the plant's size (Will and van Bel 2006). However, short generation times an extremely high asexual fecundity can result in a rapid increase in aphid population density and subsequently elevated consumption levels of phloem sap (Anna *et al*. 2008).

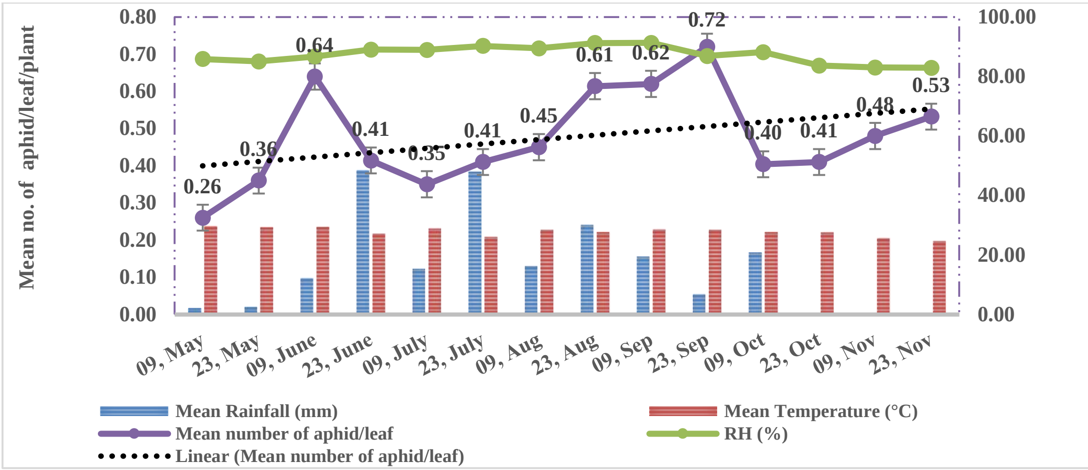


Figure 4.3.1.1(a) Dynamics of aphid infested leaves plant^{-1} on chili in jhum field at Bandarban during 2015.

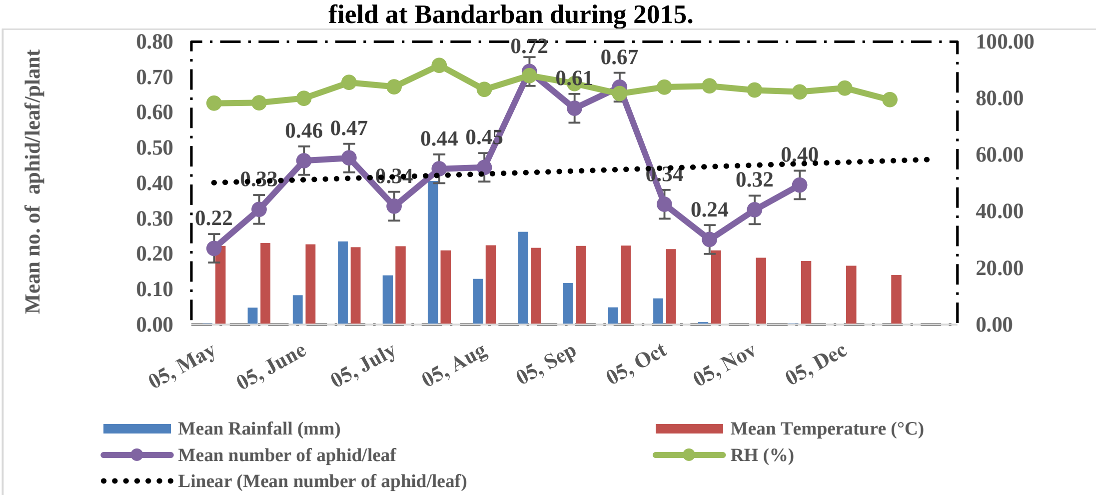


Figure 4.3.1.1(b) Dynamics of aphid infested leaves plant^{-1} on chili in jhum field at Rangamati during 2015.

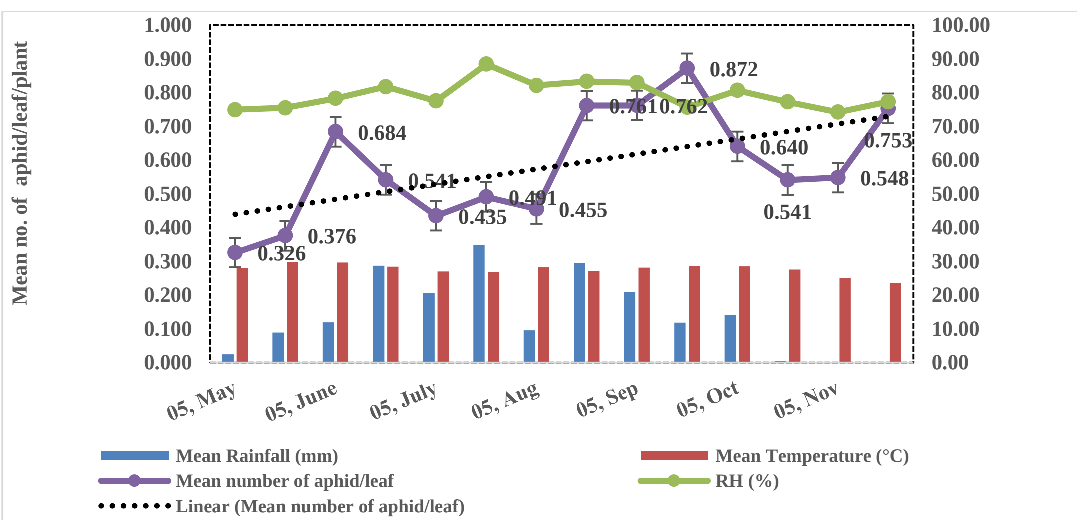


Figure 4.3.1.1(c) Dynamics of aphid infested leaves plant^{-1} on chili in jhum field at Khagrachari during 2015.

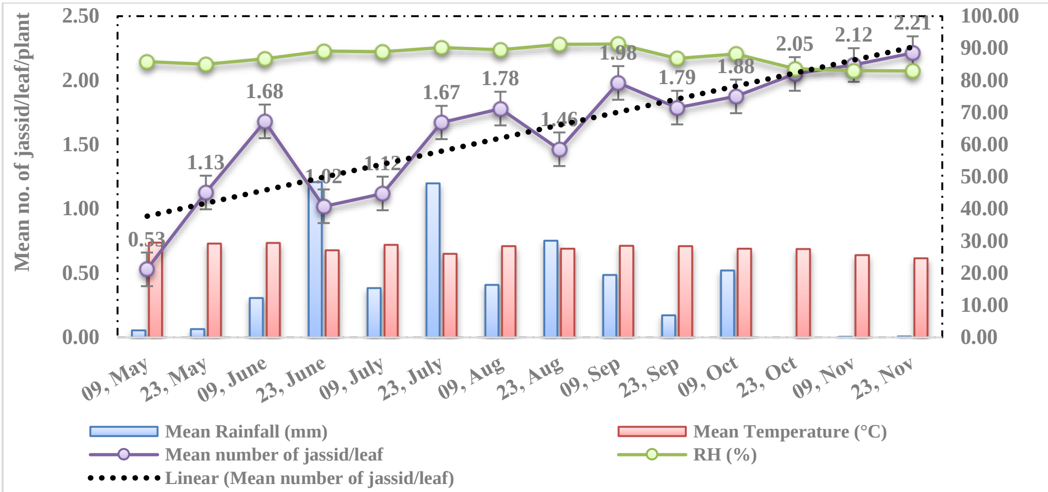


Figure 4.3.1.2(a) Population dynamics of jassid on chili in jhum field at Bandarban during 2015.

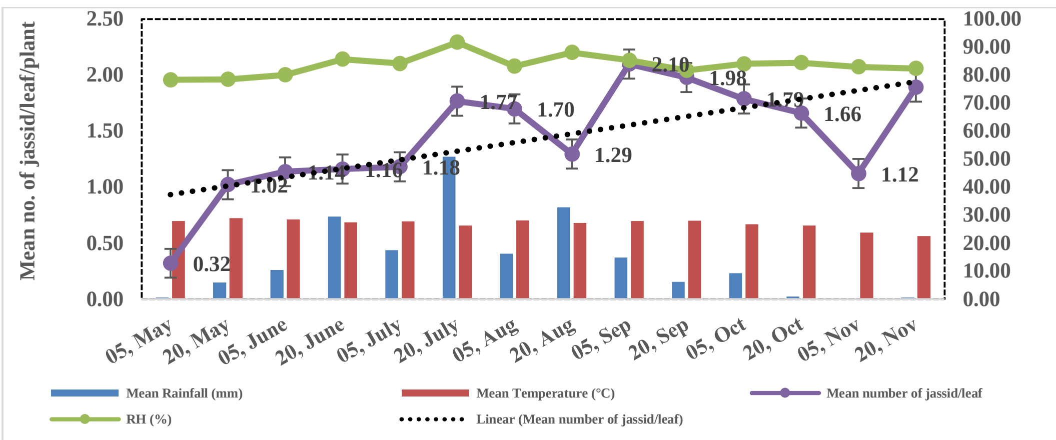


Figure 4.3.1.2 (b) Population dynamics of jassid on chili in jhum field at Rangamati during 2015.

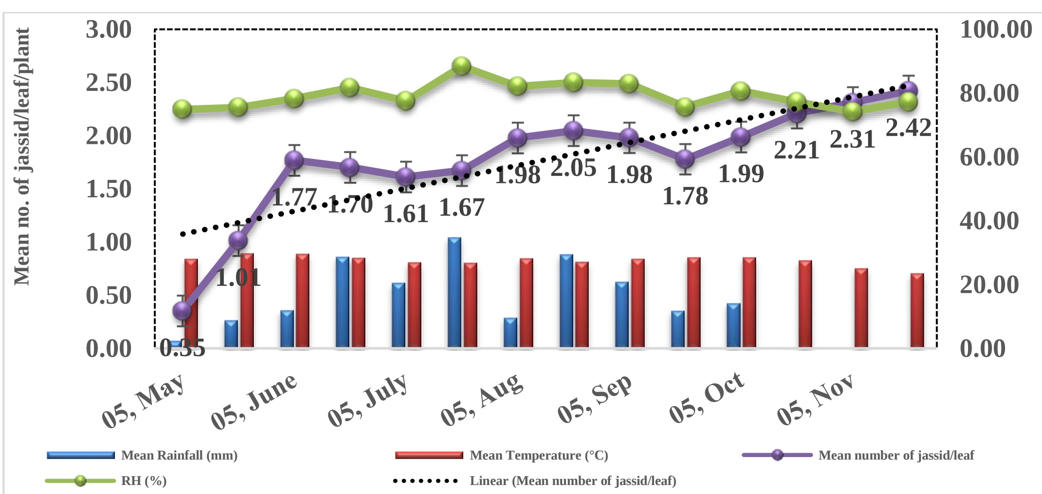


Figure 4.3.1.2 (c): Population dynamics of jassid on chili in jhum field at Khagrachari during 2015.

4.3.1.2 Population dynamics of jassid of chili in jhum field

During the year 2015, population levels of jassid attacking chili at all hill districts are shown in Figure 4.3.1.2 (a, b and c). Figures revealed that jassid infestation started at the early stage of chili plant arise from the jhum field with a number of jassid leaf^{-1} were only 0.53, 0.32 and 0.35 at Bandarban, Rangamati and Khagrachari, respectively during early week of May. Then a number of jassid leaf^{-1} were gradually increased in the 2nd week of June at Bandarban (1.68), and 1st week of June at Khagrachari (1.77) with the increase of relative humidity and rainfall. Although, the number of jassid leaf^{-1} were gradually increased 3rd week of May and remain steady population before the 3rd week of July. With increased rainfall at Bandarban the population declined rapidly (1.02) and then gradually increased mean number jassid leaf^{-1} on the advanced stage of crop at all hill districts and reached the of maximum 2.42, and 2.21 at Khagrachari and Bandarban, respectively. While population reached a peak (2.10) in the 1st week of September then slightly declined the population and again reached to the 2nd highest peak (1.89) at the advanced crop stage at Rangamati. Additionally, the temperature decreased with little mean rainfall at all the experimental field of hilly districts creates a trend of the mean number of jassid leaf^{-1} during 2015 and was amplified undeviating at all the experimental jhum field except Rangamati. Findings of the present experiment were agreement with the findings of Moanaro and Jaipal (2018), Bugti *et al*. (2014). They described the maximum abundance during September to October and environmental variables played significant role in distribution and abundance of jassid population on capsicum and chili.

4.3.1.3 Population dynamics of thrips of chili in jhum field

During both year of 2015 and 2016, population levels of thrips attacking chili leaves at all hill districts are shown in Figure 4.3.1.3 (a, b and c). Figures revealed that very few numbers of thrips infestation started at the early stage of chili plant grown in from the jhum field. The overall trend of population dynamics at all experimental fields of hill districts during 2015 year was positively linear. With the increase of rainfall, thrips infestation gradually increased and reached the highest number of thrips leaf^{-1} 2.78, 2.26 and 2.67 in the 1st week, 2nd week of and 3rd week of September correspondingly at Khagrachari, Bandarban and Rangamati, respectively. With the decline of rainfall and temperature it slightly decline the population at the advanced stage of crop of both Rangamati and Khagrachari experimental fields whereas, at Bandarban number of thrips leaf^{-1} decreased with the increased mean rainfall during 1st week of October, then population increased at the later stage of the crop with no rainfall. The present finding are more or less similer to the finding of earlier researchers, Moanaro and Jaipal (2018) who stated that correlation analysis between thrips population and weather parameters indicated negative correlation between the number of thrips and rainfall.

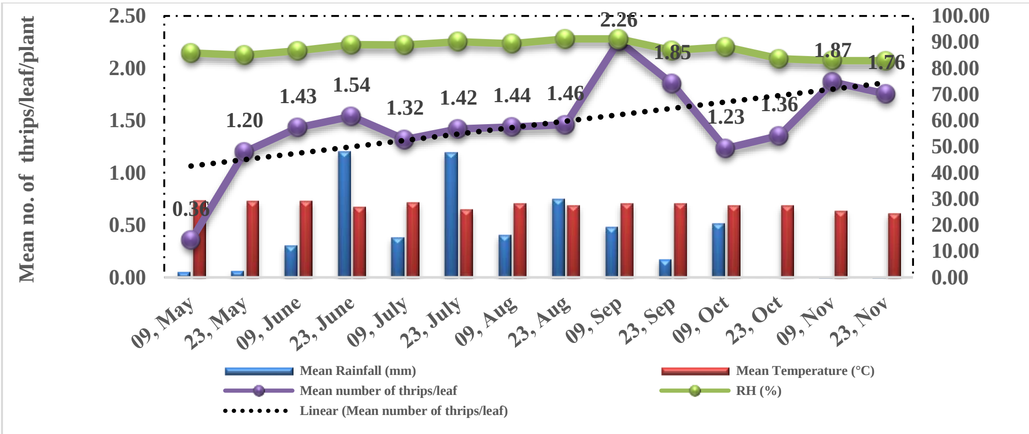


Figure 4.3.1.3 (a) Population dynamics of thrips on chili in jhum field at Bandarban during 2015.

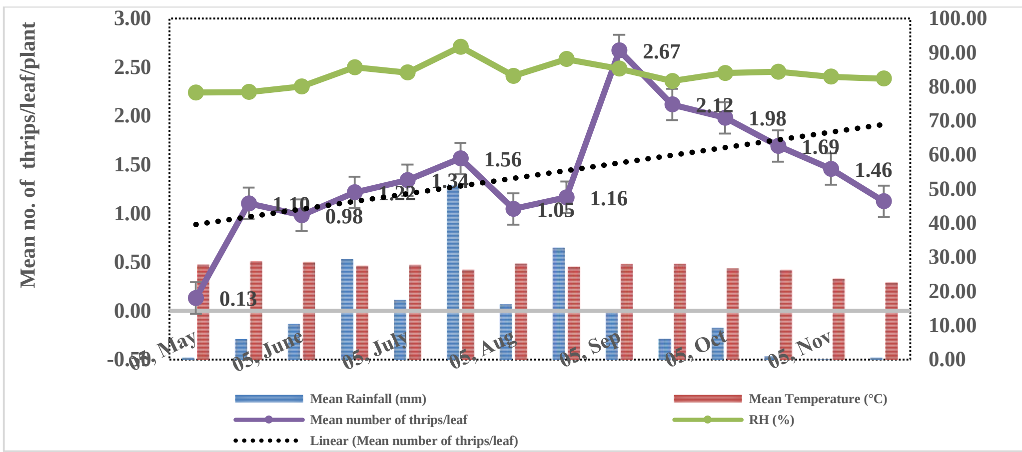


Figure 4.3.1.3 (b) Population dynamics of thrips on chili in jhum field at Rangamati during 2015.

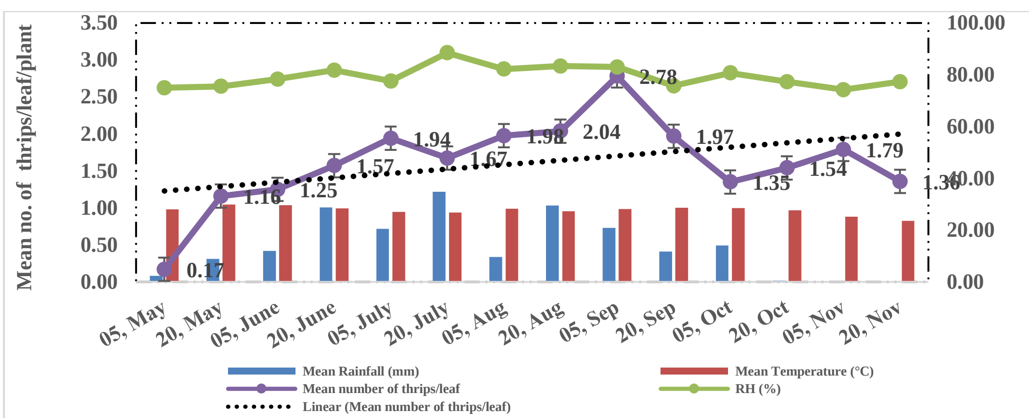


Figure 4.3.1.3 (c) Population dynamics of thrips on chili in jhum field at Khagrachari during 2015.

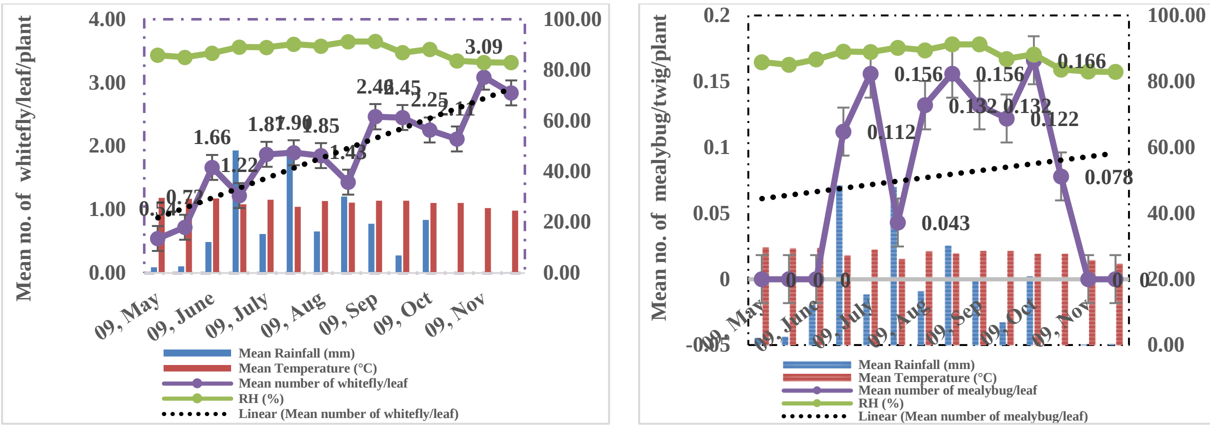


Figure 4.3.1.4 (a) and 4.3.1.5 (a) Population dynamics of whitefly and mealybug respectively on chili in jhum field at Bandarban during 2015 respectively.

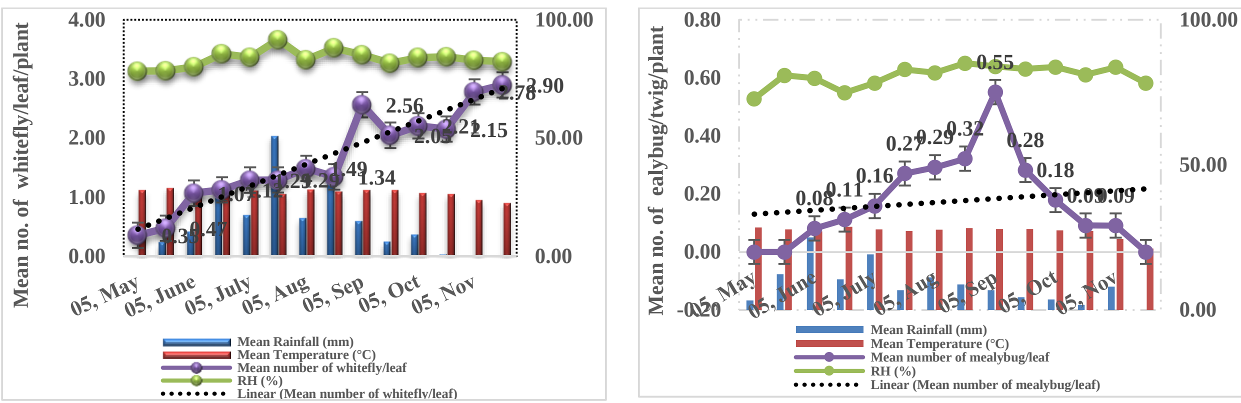


Figure 4.3.1.4 (b) and 4.3.1.5 (b) Population dynamics of whitefly and mealybug respectively on chili in jhum field at Rangamati during 2015.

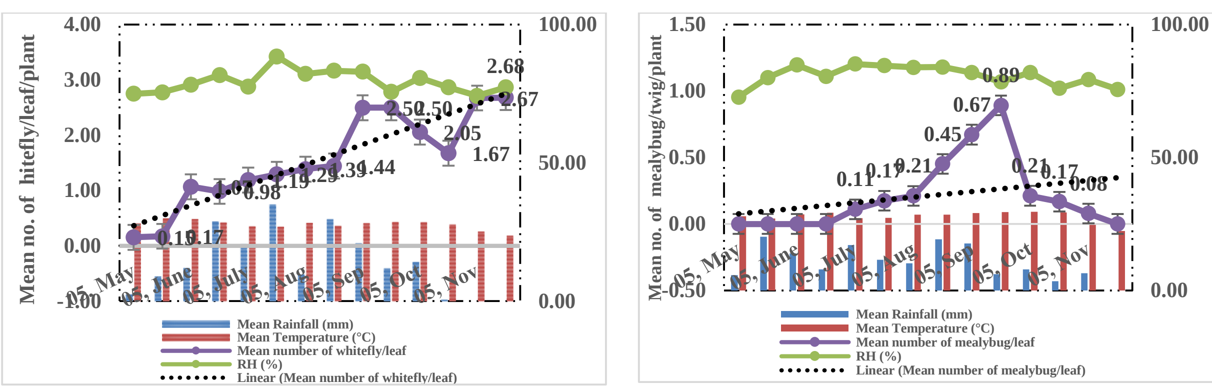


Figure 4.3.1.4 (c) and 4.3.1.5 (c) Population dynamics of whitefly and mealybug respectively on chili in jhum field at Khagrachari during 2015.

4.3.1.4 Population dynamics of whitefly of chili in jhum field

During the year 2015, population levels of whitefly attacking chili leaves at all hilly districts are shown in Figure 4.3.1.4 (a, b and c). Figures revealed that very few numbers of whitefly infestation started at the early stage of chili plant grown from the jhum field. The overall trend of population dynamics at Bandarban, Rangamati and Khagrachari experimental fields during years 2015 were linear. During the year 2015, with increasing of mean rainfall and temperature population number leaf^{-1} increase slowly up to 3rd and 4th week of August and then increased sharply with decrease of mean rainfall and temperature and reached the highest 3.09 and 2.78 at Rangamati and Bandarban, respectively. Whereas, population remain more or less constant up to1st week of September at Khagrachari and then increased slowly and again the number of the population fell 1st week of November, due to higher rainfall than the other two regions. With low temperature and no rainfall, number of whitefly increased and reached the highest (2.68) as the same trend was observed in other two experimental fields. Similarly, whiteflies also showed positive correlation with temperature and relative humidity and a negative correlation with rainfall results are in conformation with the finding of Moanaro and Jaipal (2018) and Sunitha (2007).

4.3.1.5 Population dynamics of mealybug of chili in jhum field

During the year 2015, population levels of mealybug attacking chili at all hilly districts are shown in Figure 4.3.1.5 (a, b and c). Figures revealed that mealybug infestation started after fifty days of chili planting in the jhum field but number of mealybug twig^{-1} were found very few 0.11, 0.11 and 0.09 at Bandarban, Rangamati and Khagrachari, respectively between 4th week of June at Bandarban and end of the 3rd week of June at Rangamati and Khagrachari. With increasing mean rainfall and humidity the number mealybug twig^{-1} at Rangamati and Khagrachari reached the maximum of 0.22 in the 3rd week of August at Rangamati whereas, both Khagrachari and Bandarban population reached the highest 0.18 and 0.16 at 1st and 2nd week of October. At Bandarban, with increasing mean rainfall, population abruptly declined 0.04 4th week of July. With the advances of crop growth at all hill districts, population declined sharply and not hindered crop growth throughout the season. The present experiment were in agreement with the findings of Bugti *et al*. (2014) and Sunitha (2007). They mentioned that the maximum abundance of during end of September to mid-October also added environmental variables played significant role in distribution and abundance of mealybug population on capsicum and chili.

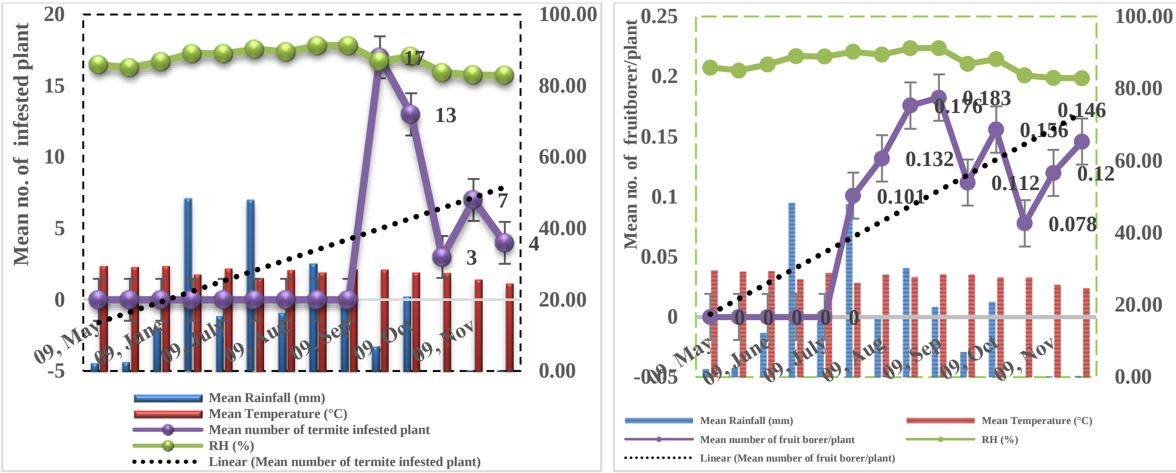


Figure 4.3.1.6 (a) and 4.3.1.7 (a) Population dynamics of termite and fruit borer on chili respectively in jhum field at Bandarban during 2015.

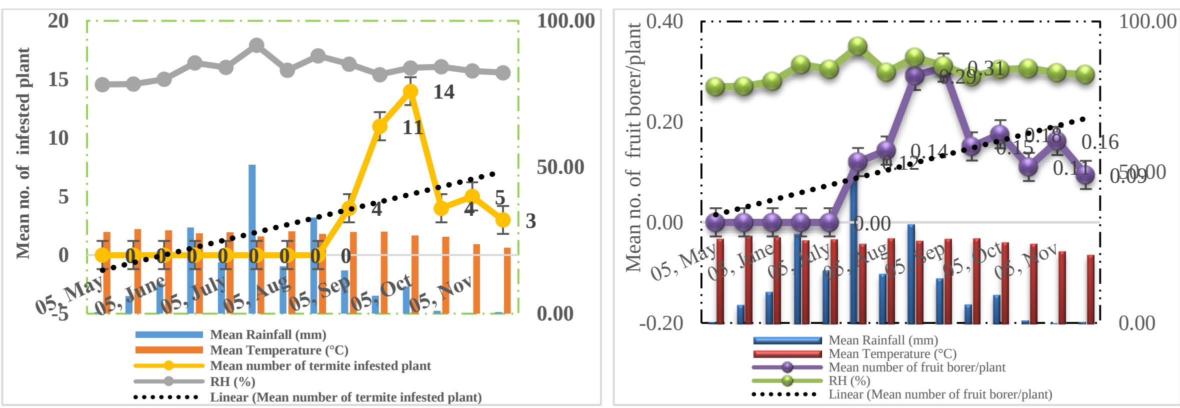


Figure 4.3.1.6 (b) and 4.3.1.7 (b) Population dynamics of termite and fruit borer on chili respectively in jhum field at Rangamati during 2015.

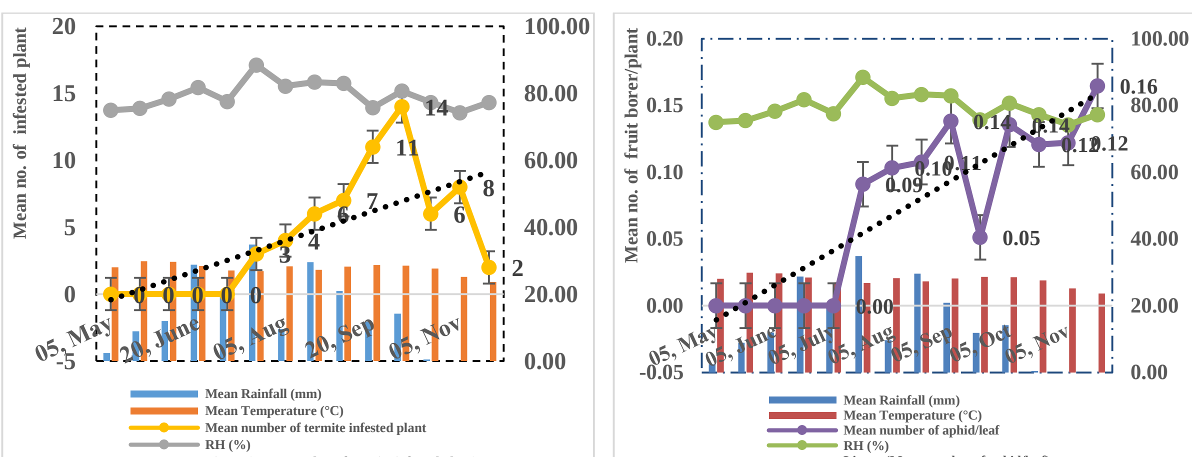


Figure 4.3.1.6 (c) and 4.3.1.7 (c) Population dynamics of termite and fruit borer on chili respectively in jhum field at Khagrachari during 2015.

4.3.1.6 Population dynamics of termite of chili in jhum field

During the year 2015, population levels of termite attacking chili at all hill districts are shown in Figure 4.3.1.6 (a, b and c). Figure 4.3.1.6 (a, b and c) revealed that termite infestation started after eighty days of chili planting in the jhum field at Khagrachari while infestation stated much later stage i.e., (1st and 4th week of September) of the crop growth at both Bandarban and Rangamati. With decreasing of mean rainfall and temperature mean infestation number of plants (17) the termite touched peak at Bandarban whereas, the highest 14 plants infested both Rangamati and Khagrachari experimental field during 1st week of October. Then at all the three hill experimental fields, termite infestation declined sharply. The trend of the mean number of termite infested plant during both 2015 and 2016 was restricted later stage of the crop with optimistic linear at all experimental jhum field of Bandarban, Rangamati and Khagrachari. Bugti *et al*. (2014) and Abdulahi (1992) revealed from their finding that termite also caused devastation on chili plant which was in agreement with present finding.

4.3.1.7 Population dynamics of fruit borer of chili in jhum field

During the year 2015 population levels of fruit borer attacking chili at all hill districts are shown in Figure 4.3.1.7 (a, b and c). Figures revealed that fruit borer infestation started after eighty days of chili planting in the jhum field. The number of fruit borer were very few (0.10, 0.12 and 0.09) at Bandarban, Rangamati and Khagrachari, respectively between 4th week of July at Bandarban and at end of the 3rd week of July at Rangamati and Khagrachari. With decreasing of mean rainfall, humidity and temperature population declined at the end of the jhum season. The overall tendency of the population in both the year showed the positive linear infestation. The results agreed with the finding of Bugti *et al*. (2014). They mentioned that the borer infestation were less than the sucking pests of green chili.

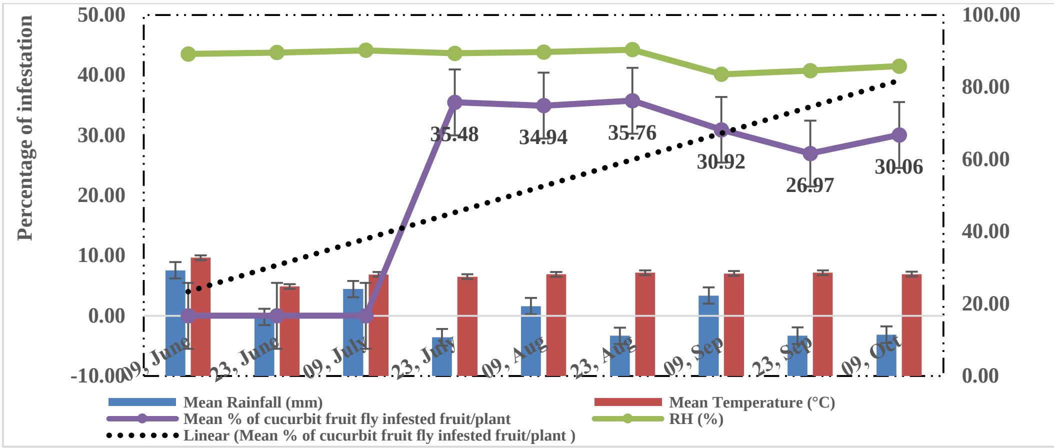


Figure 4.3.1.8 (a) Fruit fly infested fruit on marpha in jhum field at Bandarban, 2016.

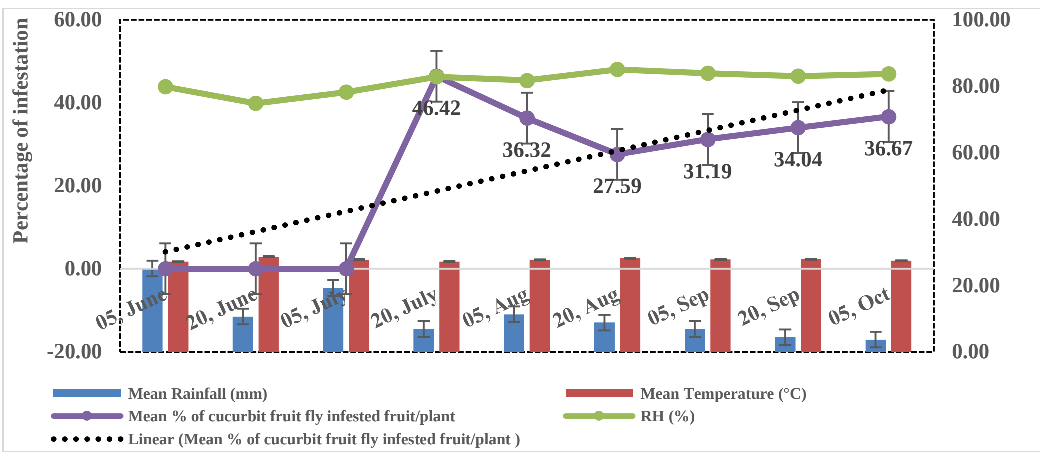


Figure 4.3.1.8 (b) Fruit fly infested fruit on marpha in jhum field at Rangamati, 2016.

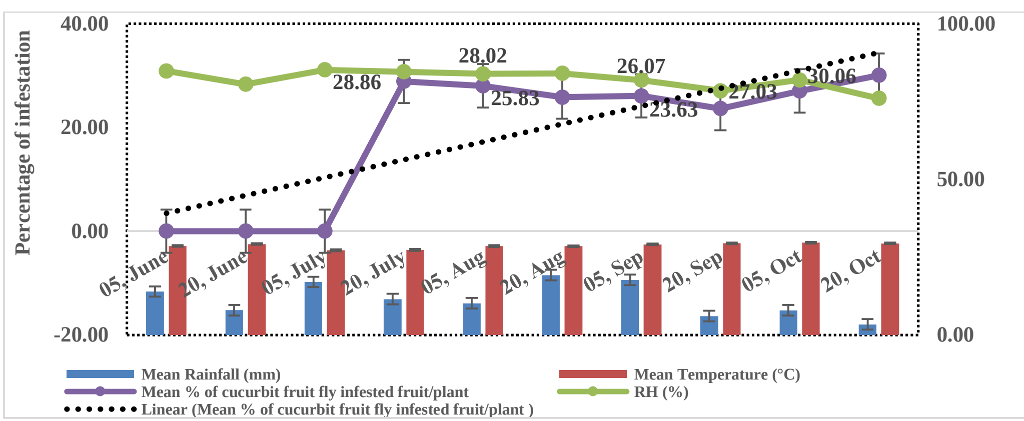


Figure 4.3.1.8 (c) Fruit fly infested fruit on marpha in jhum field at Khagrachari, 2016.

4.3.1.8 Dynamics of fruit fly infestation on marpha in jhum field

During the year 2016, population levels of fruit fly attacking marpha at all hill districts are shown in Figure 4.3.1.8 (a, b and c). Figures revealed that the mean percentage of fruit fly-infested fruit plant^{-1} started after fruit set *i.e*., at end of the 3rd week of July in marpha of jhum experimental fields. With decreased mean rainfall, percentage of fruit fly-infested fruit plant^{-1} was the highest (46.42%) during the initial infestation when the number of fruits are few at Rangamati. Then infestation slightly declined up to the 3rd week of August and subsequently, the infestation was slowly increased at the later stage of the crop. The similar infestation was observed on the other experimental fields, in addition, reached a maximum 35.76% and 30.06% during the 4th week of August and also 1st week of October at Bandarban and Khagrachari, correspondingly. The overall trend of percent of fruit fly-infested fruit plant^{-1} were positive linear and significantly damage the fruit at all hilly experimental fields of Bandarban, Rangamati and Khagrachari. Among the three experimental fields, a comparatively higher percentage of infestation was detected at Rangamati whereas the other two districts had the similar percentage of infestation during the fruit setting of Marpha in jhum. Present study were in agreement with several researchers (Mandal 2015, Uchôa 2012, Kumar *et al*. 2011 and Ronald 2003). They mentioned that the fruit flies of genus *Bactrocera* have great economic importance because they are considered the key pests that most adversely affect the production and marketing of vegetables and fruits around the world.

4.3.1.9 Dynamics of red pumpkin beetle infestation on marpha in jhum field

During the year 2016, infestation levels of red pumpkin beetle attacking marpha leaves at all hill districts are shown in Figure 4.3.1.9 (a, b and c). Figures revealed that mean percentage of red pumpkin beetle-infested leaves plant^{-1} started from seedling stage in the jhum fields with percent infestation of 19.30, 17.52 and 17.56 during the end of the 3rd week of June at Bandarban, Rangamati and Khagrachari, respectively. The percent of red pumpkin beetle infestation were abruptly amplified and reached the maximum 40.09, 38.14 and 38.00 in the 1st and 2nd week of July at Rangamati, Khagrachari and Bandarban, separately. Though infestation at Bandarban was declined a little up to 4th week of July and then shortly declined its infestation as well continue without significant loss of the crop at rest of the season. In case of other experimental fields of two hilly regions just after the all-out infestation *i.e*., during the 2nd week of July to 1st week of August the percentage of infestation dropped moderately. The overall trend of percentage of red pumpkin beetle infestation with a duration of the season, a negative linear likewise equivalent percentage of infestation was revealed from Bandarban, Rangamati and Khagrachari experimental jhum fields.

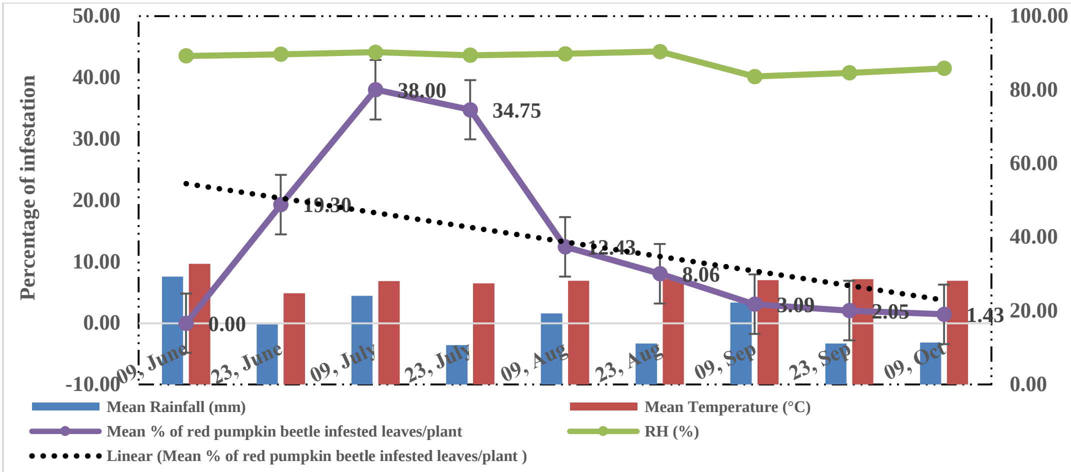


Figure 4.3.1.9 (a) Seasonal red pumpkin beetle infested leaves on marpha in jhum field at Bandarban during 2016.

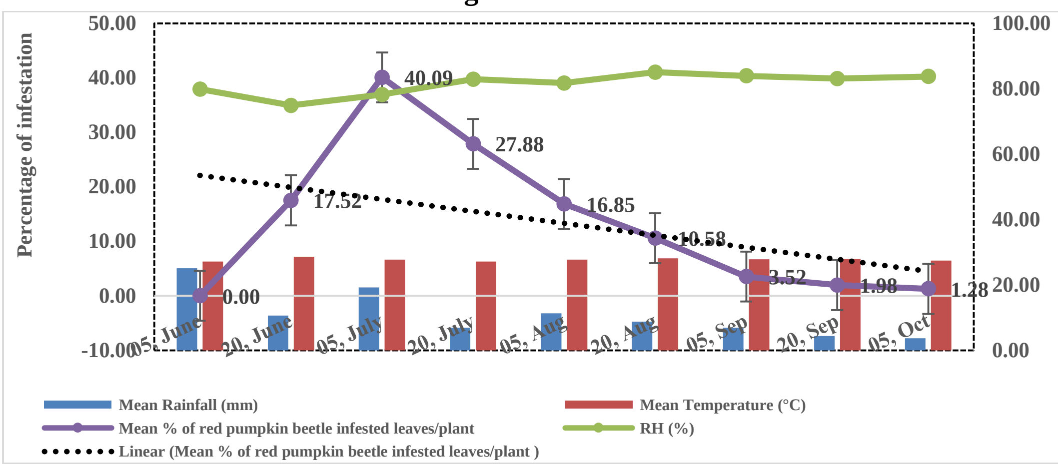


Figure 4.3.1.9 (b) Seasonal red pumpkin beetle infested leaves on marpha in jhum field at Rangamati during 2016.

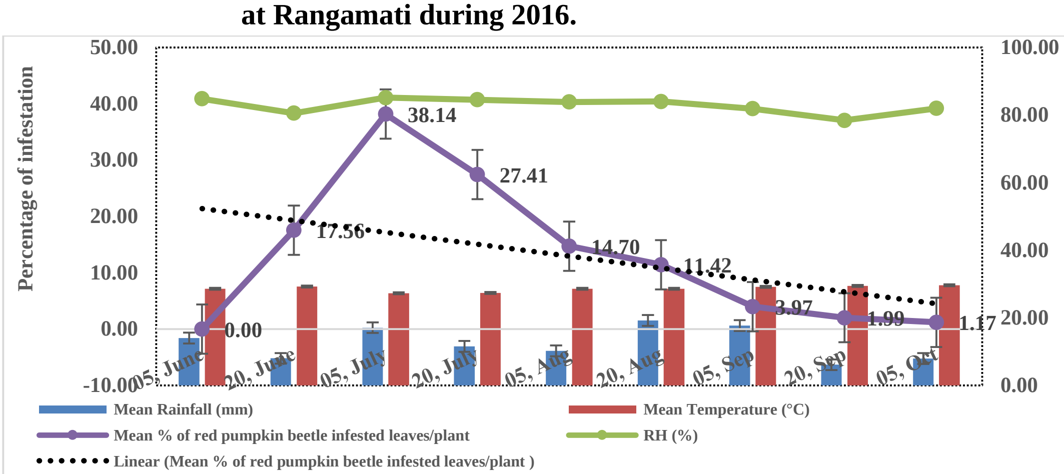


Figure 4.3.1.9 (c) Seasonal red pumpkin beetle infested leaves on marpha in jhum field at Khagrachari during 2016.

4.3.1.10 Dynamics of jassid infestation on marpha in jhum field

During the year 2016, infestation levels of jassid attacking marpha leaves at all the hill districts are shown in Figure 4.3**.**1.10 (a, b and c).

Figures revealed that mean percentage of jassid infested leaves plant^{-1} started at seedling of marpha in jhum fields with little infestation percentage of 0.05, and 0.54 during the end of the 4th and 3rd week of June at Bandarban, Rangamati correspondingly whereas at Khagrachari infestation was 0.49 during 1st week of June. After early infestation of leaves plant^{-1} by jassid**,** percentage of infestation were sharply increased and reached a maximum of 27.95, 25.47 and 25.16 for the period of the end of 3rd, 4th week of June and 1st week of July at Rangamati, Bandarban and Khagrachari, separately. Then the jassid infestation harshly declined at all the three hill districts.

After increased number of leaves initiated on the marpha plant it caused an insignificant percentage of infestation at the later stage of the crop at all experimental fields of hill districts. The general trend of percentage of jassid infestation during the season was negative linear likewise the corresponding percentage of infestation revealed from experimental jhum fields of Bandarban, Rangamati and Khagrachari.

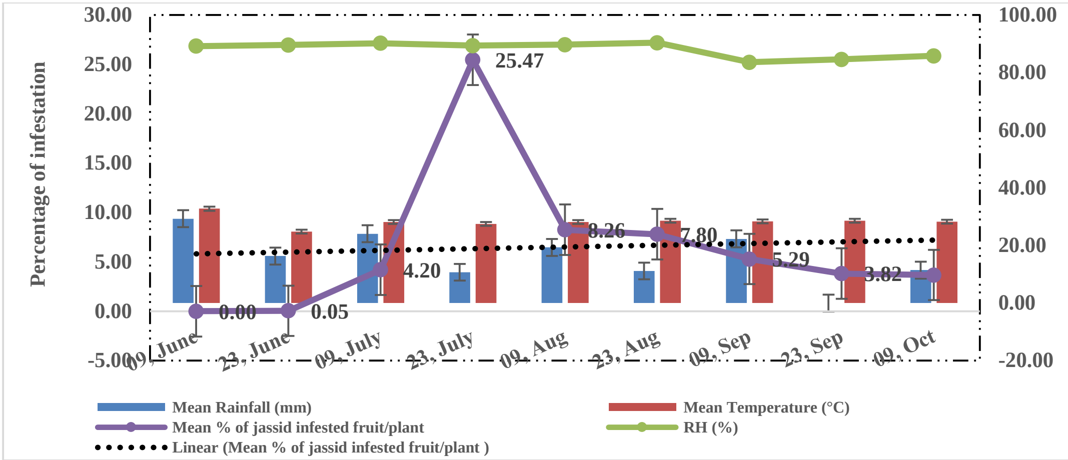


Figure 4.3.1.10 (a) Seasonal percentage of jassid infested leaves on marpha in jhum field at Bandarban during 2016.

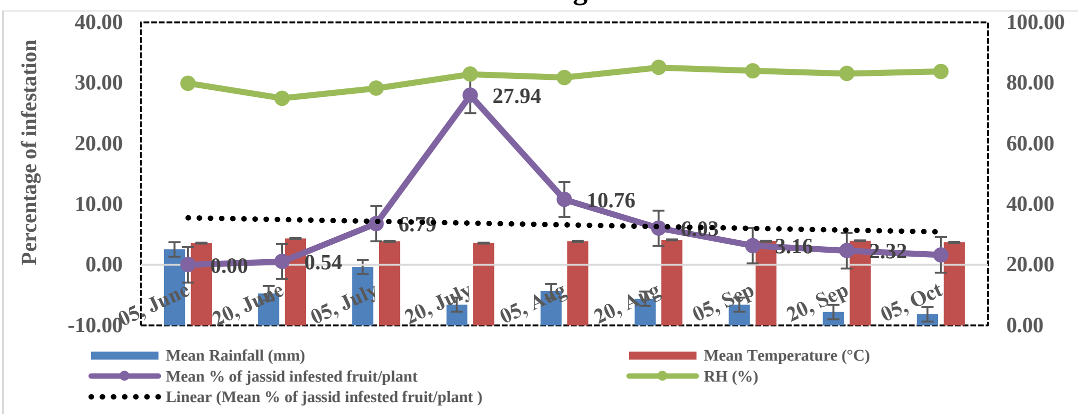


Figure 4.3.1.10 (b) Seasonal percentage of jassid infested leaves on marpha in jhum field at Rangamati 2016.

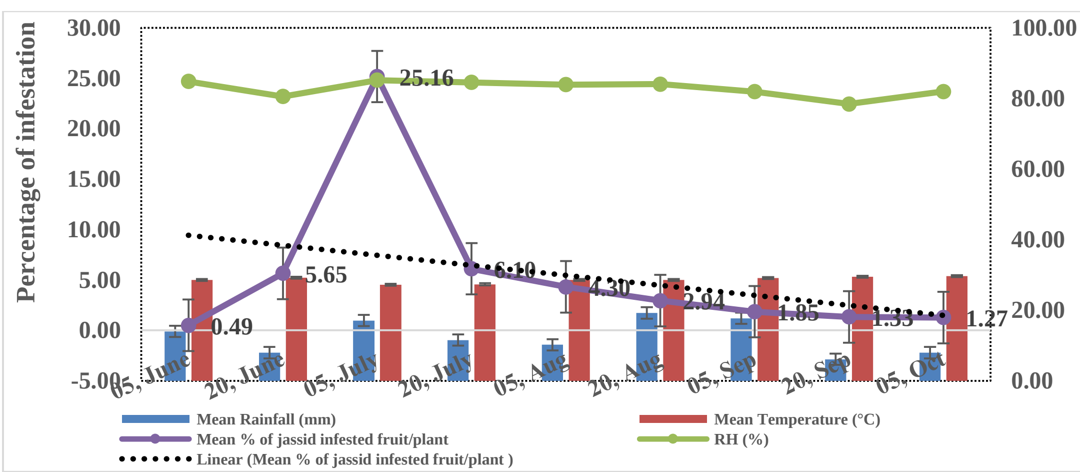


Figure 4.3.1.10 (c) Seasonal percentage of jassid infested leaves on marpha in jhum field at Khagrachari 2016.

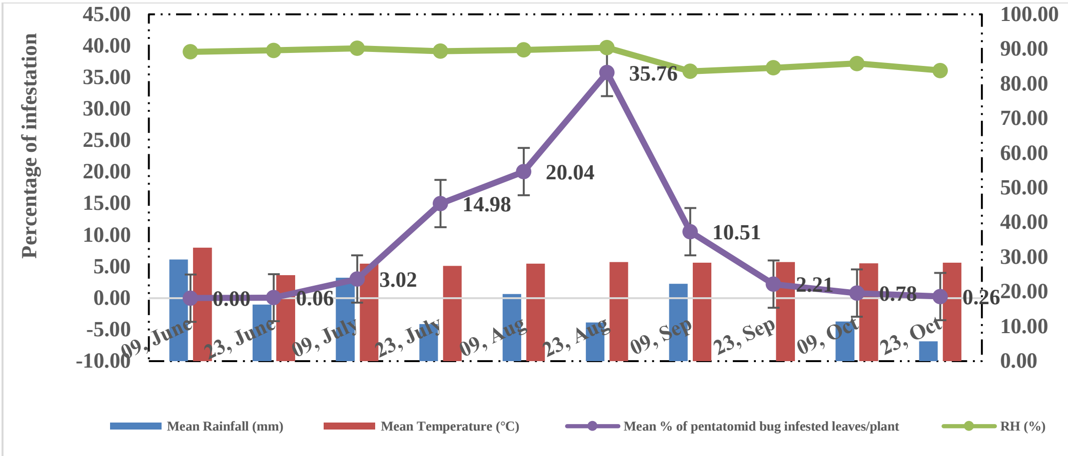


Figure 4.3.1.11 (a) Seasonal pentatomid bug infested leaves on marpha in jhum field at Bandarban 2016.

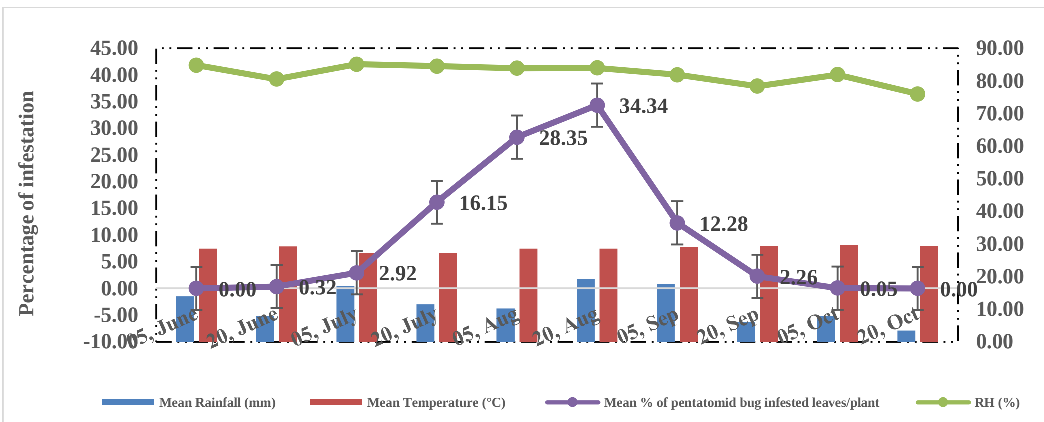


Figure 4.3.1.11 (b) Seasonal pentatomid bug infested leaves on marpha in jhum field at Rangamati during 2016.

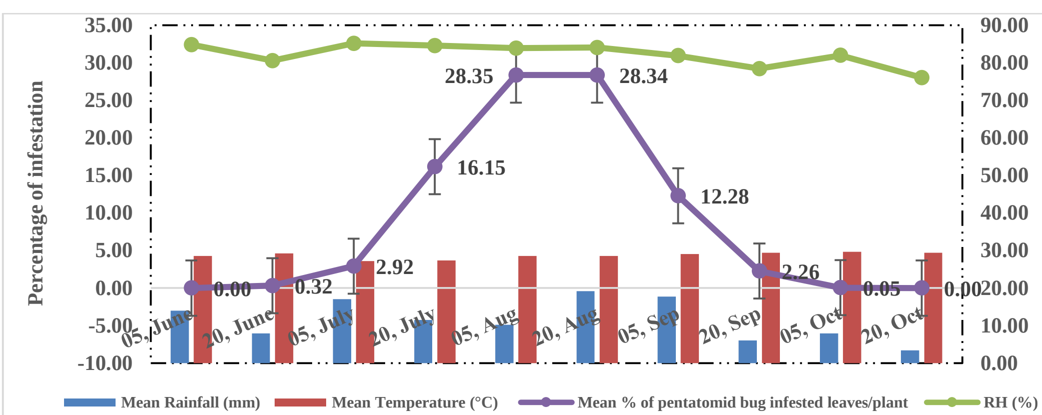


Figure 4.3.1.11 (c) Seasonal pentatomid bug infested leaves on marpha in jhum field at Khagrachari 2016.

4.3.1.11 Dynamics of pentatomid bug infestation on marpha in jhum field

During the year 2016, infestation levels of pentatomid bug attacking marpha leaves at all the hill districts are shown in Figure 4.3.1.11 (a, b and c).

Figures revealed that mean percent infestation of pentatomid bug infested leaves plant^{-1} started very slowly at the end of the 3rd week of June at Rangamati and Khagrachari whereas at Bandarban started of the 2nd week of June with a similar trend. Thereafter pentatomid bug infestation was progressively increased and reached a maximum (46.42%) on 1st week of August at Rangamati. However, the infestation percent reached a peak of 35.76% and 34.34% 4th and end of 3rd week of August at Bandarban and Khagrachari, respectively. Among the three experimental fields comparatively higher infestation percentage observed at Rangamati.

With the decrease of mean rainfall and temperature, infestation declined abstemiously at all experimental fields of marpha at hill districts and later stage of the crop its percentage of infestation was very uncommon on leaves plant^{-1}.

4.3.1.12 Dynamics of epilachna beetle infestation on marpha in jhum field

During the year 2016, infestation levels of epilachna beetle attacking marpha leaves at all hill districts are shown in Figure 4.3.1.12 (a, b and c).

Figures revealed that mean percentage of epilachna beetle infested leaves plant^{-1}were 6.04 and 6.86, started at an early stage of the crop on the 3rd and 4th week of July at Rangamati and Bandarban correspondingly while at Khagrachari its infestation was 1.98 low level at the end of the 3rd week of June.

Then on epilachna beetle infestation were increasing and reached a maximum of 24.30, 22.54 and 18.02 duration of 3rd and 4th week of July at Khagrachari, Rangamati and Bandarban respectively. Among the three experimental fields, similar infestation rate were observed at all the three hill districts, a common trend of of the rate of epilachna beetle infestation during the season was a negative linear too corresponding percentage of infestation revealed from experimental jhum fields of Bandarban, Rangamati and Khagrachari.

With the decreased mean rainfall and temperature, infestation declined ascetically up to the 3rd week of August. Then the percentage of infestation declined with lower infestation and were observed at the later stage of marpha in jhum field of all the three experimental fields.

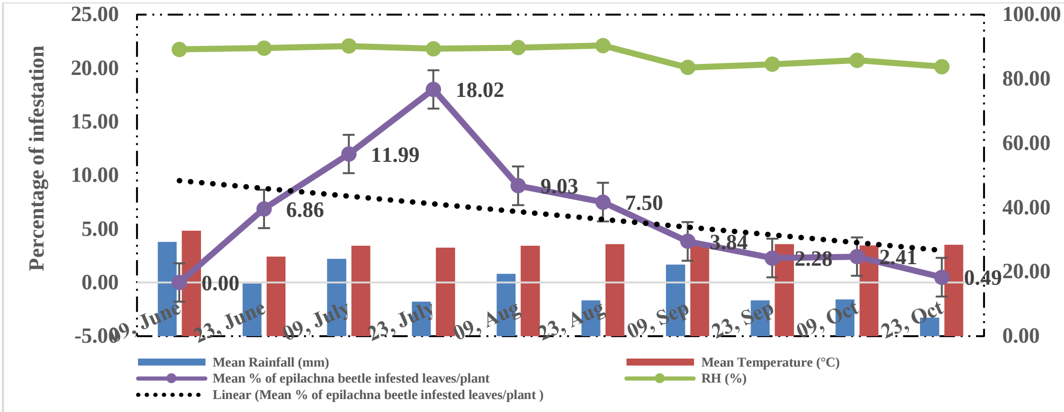


Figure 4.3.1.12 (a) Seasonal epilachna beetle infested leaves on marpha in jhum field at Bandarban 2016.

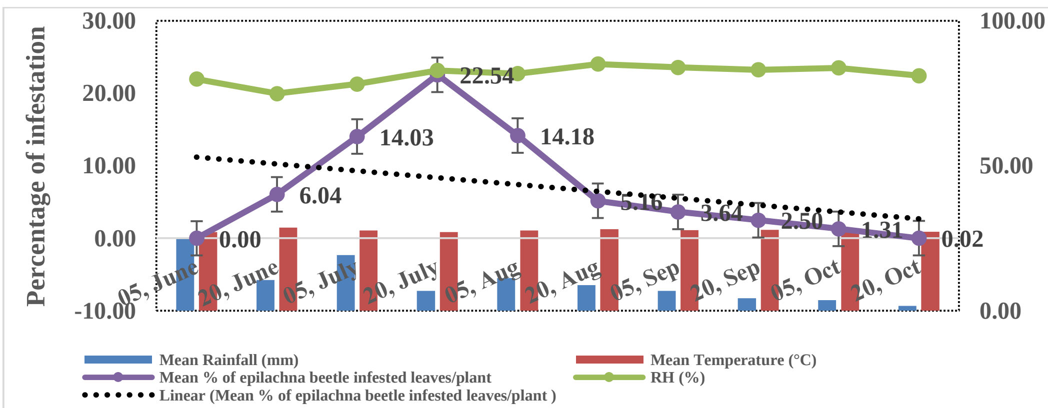


Figure 4.3.1.12 (b) Seasonal epilachna beetle infested leaves on marpha in jhum field at Rangamati 2016.

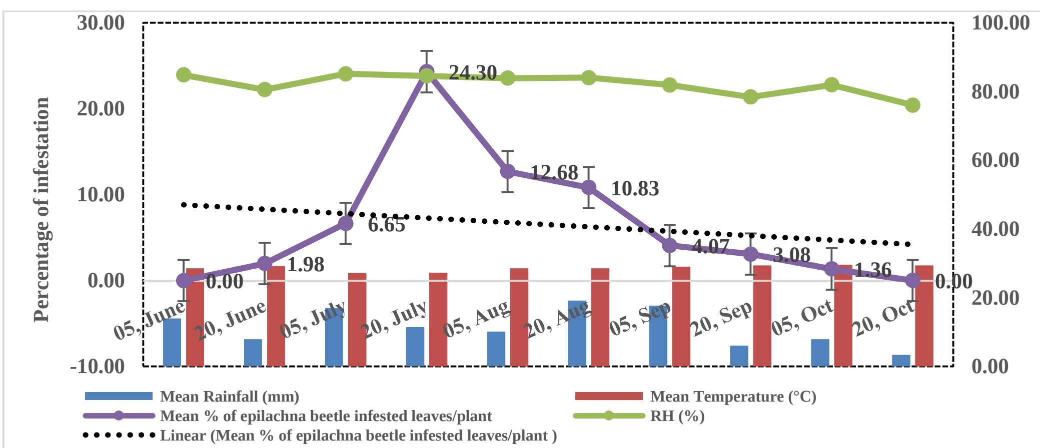


Figure 4.3.1.12 (c) Seasonal epilachna beetle infested leaves on marpha in jhum field at Khagrachari 2016.

4.3.1.13 Dynamics of leaf minor infestation on marpha in jhum field

During the year 2016, infestation levels of leaf minor attacking marpha leaves at all hill districts are shown in Figure 4.3.1.13 (a, b and c).

Figures revealed that the percentage of leaf minor infested leaves plant^{-1} were started at an early stage of the crop during the period of 2nd and 1st week of July at Bandarban and Rangamati and reached the maximum 16.18 and 15.62, correspondingly while at Khagrachari its infestation was 9.17.

After with decreased rainfall and increased temperature, infestation rate steadily increased and touched the peak of 14.95 at Khagrachari at the end of the 3rd week of July. After reaching the peak infestation, a common trend of infestation was regularly declined and at the end of August to September, infestation rate were insignificant in terms of the abundant number of leaves at all the experimental fields of Bandarban, Rangamati and Khagrachari.

Trend of percent leaf minor infestation with seasonal incidence throughout the marpha crop life were to some extent negatively linear to corresponding percent of infestation.

4.3.1.14 Dynamics of aphid infestation on marpha in jhum field

During the year 2016, infestation levels of aphid attacking marpha leaves at all hill districts are shown in Figure 4.3.1.14 (a, b and c).

Figures revealed that percent aphid infested leaves plant^{-1} were started at an early stage of marpha young leaves during the period between 3rd and 4th week of June at all three experimental fields of hill districts of Khagrachari, Rangamat and Bandarban.

With decreased rainfall during the month of July, infestation reached the highest of 27.94 and 25.47 at Rangamati and Bandarban in that order, however, at Khagrachari it reached a peak of 25.16 at 1st week of July. After reaching the peak infestation, a common trend of infestation was suddenly declined at the end of August to September. The infestation percentage was inconsequential in terms of rich number of leaves at all the experimental fields of Bandarban, Rangamati and Khagrachari.

Basically trend of the rate of the sucking insect aphid infestation with seasonal incidence throughout the marpha crop growth were alike at all the three experimental jhum fields.

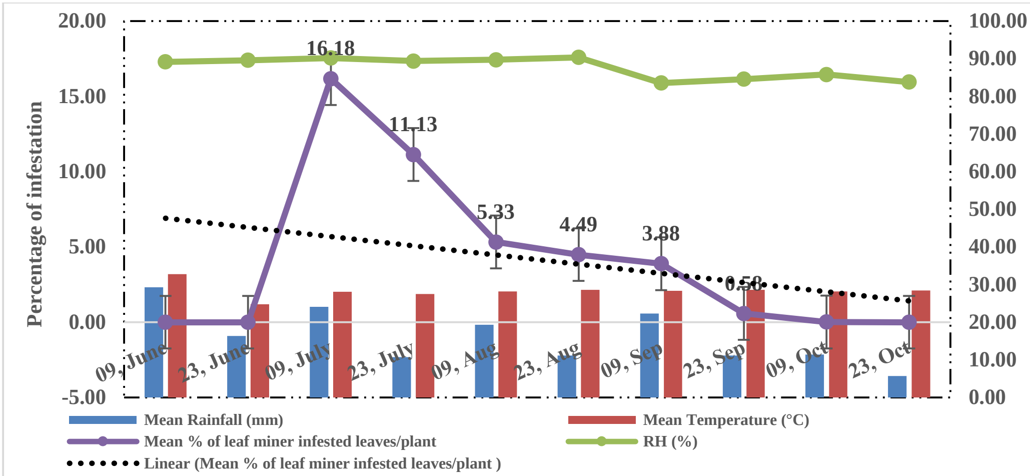


Figure 4.3.1.13 (a) Seasonal mean percentage of leaf miner infested leaves plant^{-1} on marpha in jhum field at Bandarban during 2016.

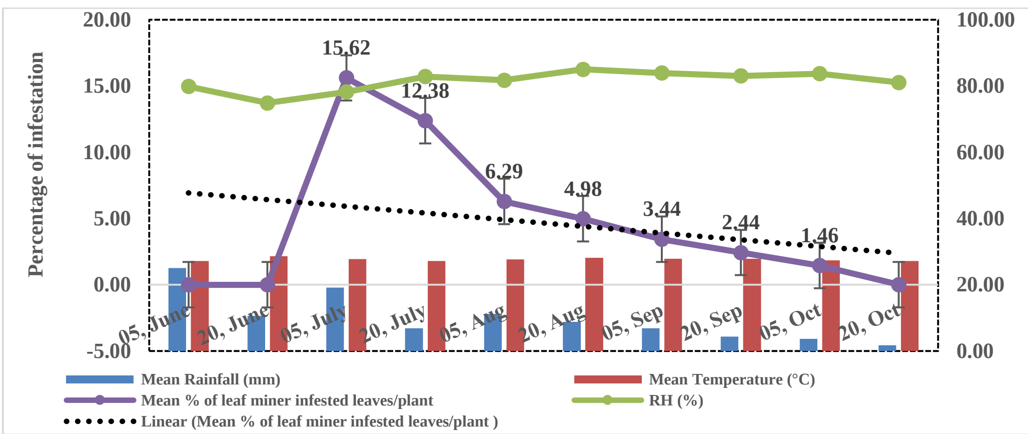


Figure 4.3.1.13 (b) Seasonal mean percentage of leaf miner infested leaves plant^{-1} on marpha in jhum field at Rangamati during 2016.

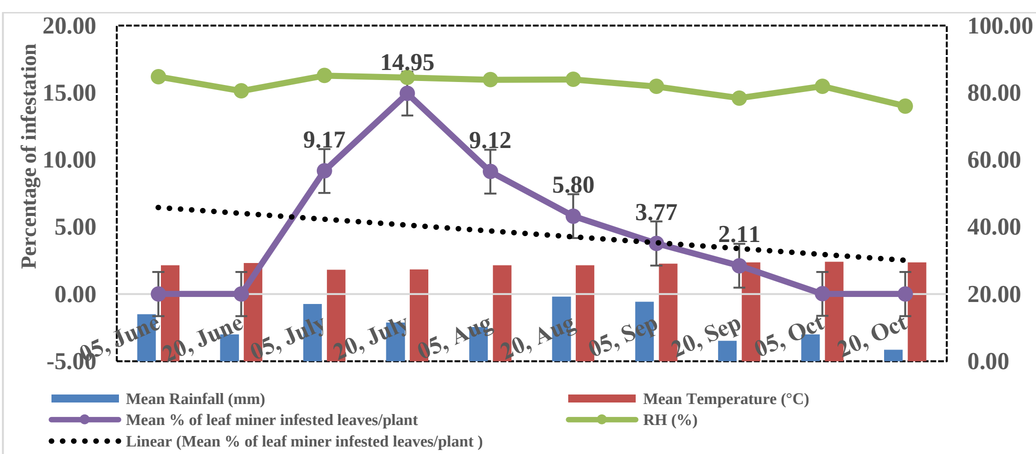


Figure 4.3.1.13 (c) Seasonal mean percentage of leaf miner infested leaves plant^{-1} on marpha in jhum field at Khagrachari during 2016.

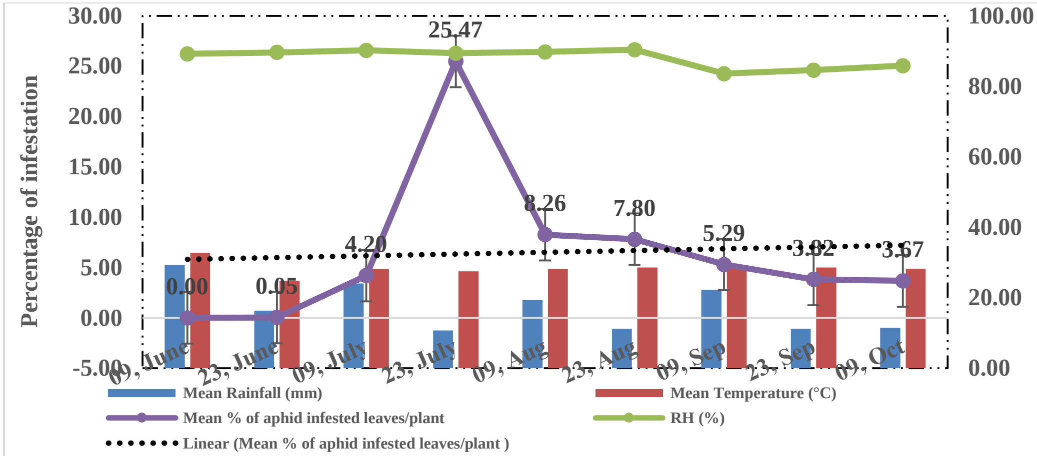


Figure 4.3.1.14 (a) Seasonal mean percentage of aphid infested leaves plant^{-1} on marpha in jhum field at Bandarban during 2016.

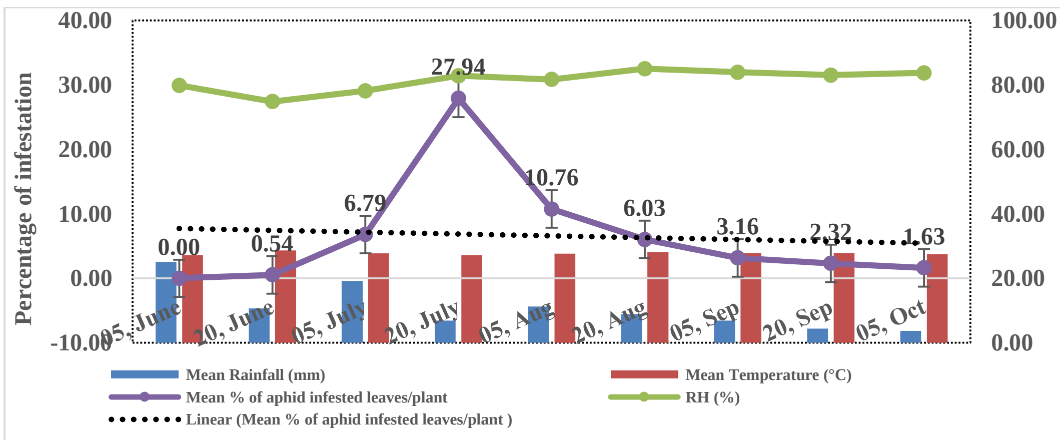


Figure 4.3.1.14 (b) Seasonal mean percentage of aphid infested leaves plant^{-1} on marpha in jhum field at Rangamati during 2016.

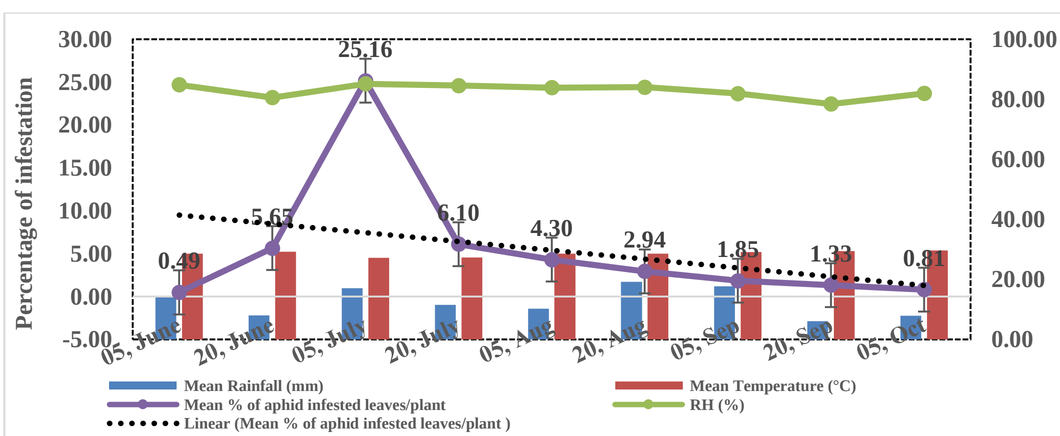


Figure 4.3.1.14 (c) Seasonal mean percentage of aphid infested leaves plant^{-1} on marpha in jhum field at Khagrachari during 2016.

4.3.1.15 Dynamics of semilooper infestation on okra in jhum field

During the year 2016, infestation levels of semilooper attacking okra leaves at all the hill districts are shown in Figure 4.3.1.15 (a, b and c). Figures revealed that mean percentage of semilooper infested leaves plant^{-1} were very scarce and started at the middle stage of okra leaves at the 1st week of August at both experimental fields Khagrachari and Rangamati and reached its highest rate of infestationof 0.77 and 0.50 during the end of the 3rd week of August. However, at Bandarban the initial infestation was much higher in compared to other two hill experimental fields for the period of 2nd week of August and then it reached a maximum of 0.28 at the 4th week of the same month and continued the same infestation rate on the 1st week of September.

Then infestation of semilooper was not observed at later stage of the crop. The similar finding revealed after reaching the peak infestation as well abruptly declined at the 1st week of September and rest of the crop season no infestation were observed at both Khagrachari and Rangamati. As a minor pest of okra, semilooper infestation were insignificant with a very short period of the total season. However, the trend of percent of chewing insect semilooper infestation with seasonal incidence throughout the okra crop was slightly negative linear at all three hill jhum experimental fields.

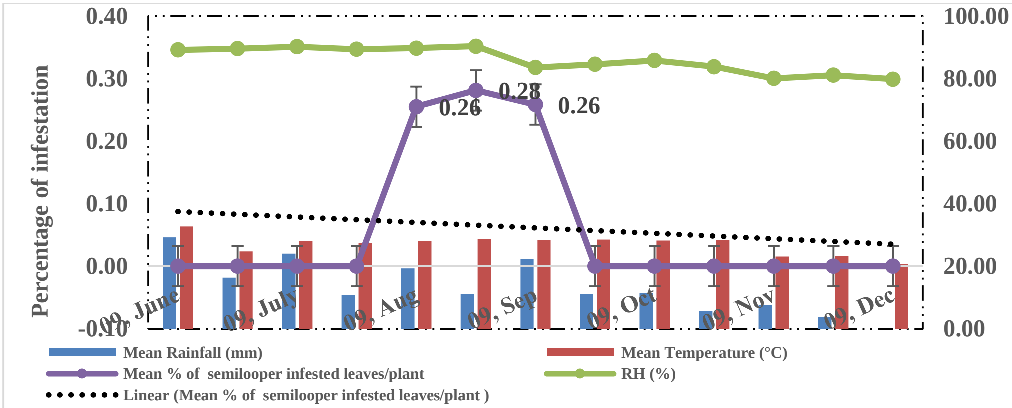


Figure 4.3.1.15 (a) Seasonal mean percentage of semilooper infested leaves plant⁻¹ on okra in jhum field at Bandarban during 2016.

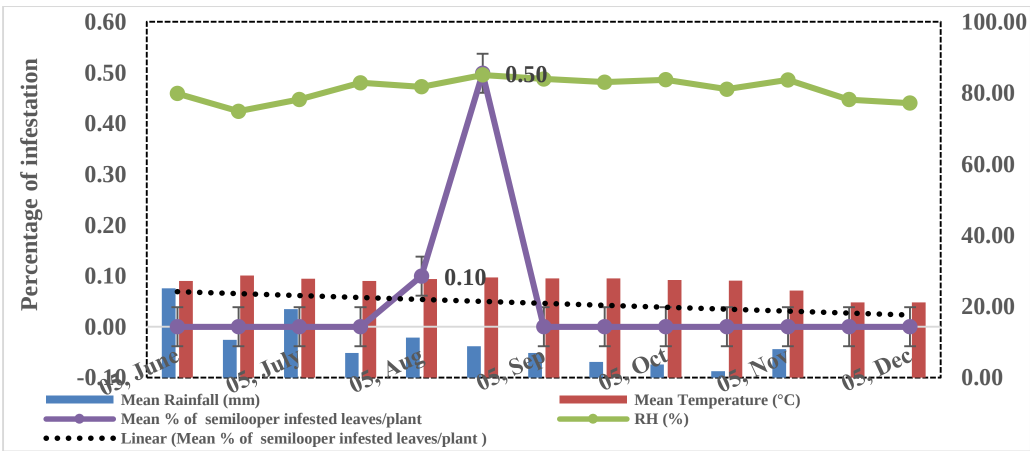


Figure 4.3.1.15 (b) Seasonal mean percentage of semilooper infested leaves plant⁻¹ on okra in jhum field at Rangamati during 2016.

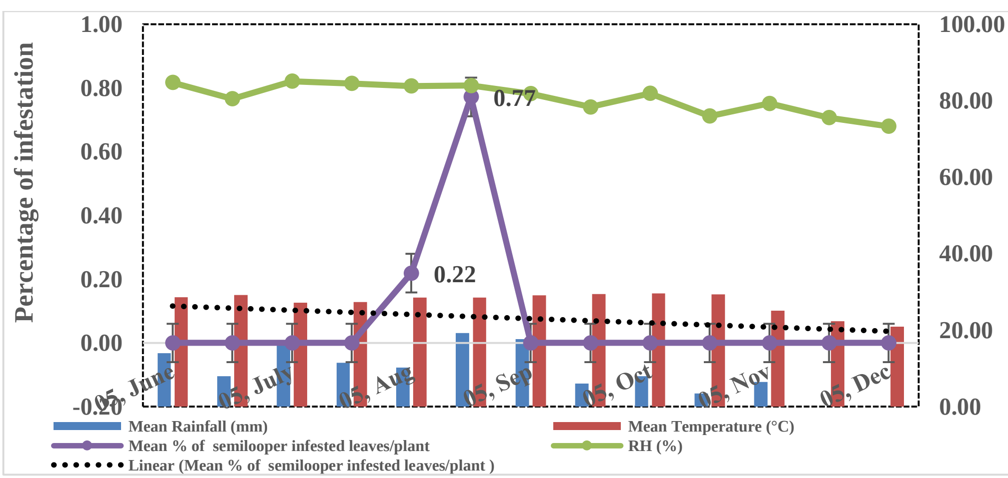


Figure 4.3.1.15 (c) Seasonal mean percentage of semilooper infested leaves plant⁻¹ on okra in jhum field at Khagrachari during 2016.

4.3.1.16 Dynamics of aphid infestation on okra in jhum field

During the year 2016, infestation levels of aphid attacking okra leaves at all the hill districts are shown in Figure 4.2.1.16 (a, b and c).

Figures revealed that the percent of aphid infested leaves plant^{-1} were started 50 days later after emerging okra plant in jhum field with an initial infestation of 17.52, 7.80 and 5.65 at Rangamati, Khagrachari and Bandarban, respectively during 1st and 2nd week of July. Then infestation aphid leaf^{-1} was gradually increased and reached the maximum of 48.28, 46.42 and 46.77 for the period of 3rd and 4th week of July with decreasing mean rainfall and increasing relative humidity at Khagrachari, Rangamati and Bandarban, correspondingly. With leisurely increasing mean rainfall and temperature during the end of July to 2nd week of September infestation declined regularly and then slightly increased, and remain more or less fixed number up to end of the crop season at Khagrachari.

Whereas, at Rangamati and Bandarban, the percentage of infestation slowly dropped up to end of 3rd and 4th week of August separately and then increased infestation. After the end of the 3rd week of September, again the infestation slightly decreased at Rangamati with decreased mean rainfall and temperature at the later stage of the crop.

In the case of the experimental field at Bandarban, the percent of aphid infestation declined more rapidly at the later stage of the season due to comparatively higher mean rainfall than the other two experimental fields. Among the three hill districts percentage of aphid infested leaves plant^{-1} were comparatively lower at Bandarban nevertheless, similar infestation rate were observed on okra in jhum fields of Rangamati and Khagrachari. The trend of mean percentage infestation of aphid leaf^{-1} during 2016 with seasonal incidence throughout the okra crop growth were positively linear at all experimental jhum field of Bandarban, Rangamati and Khagrachari.

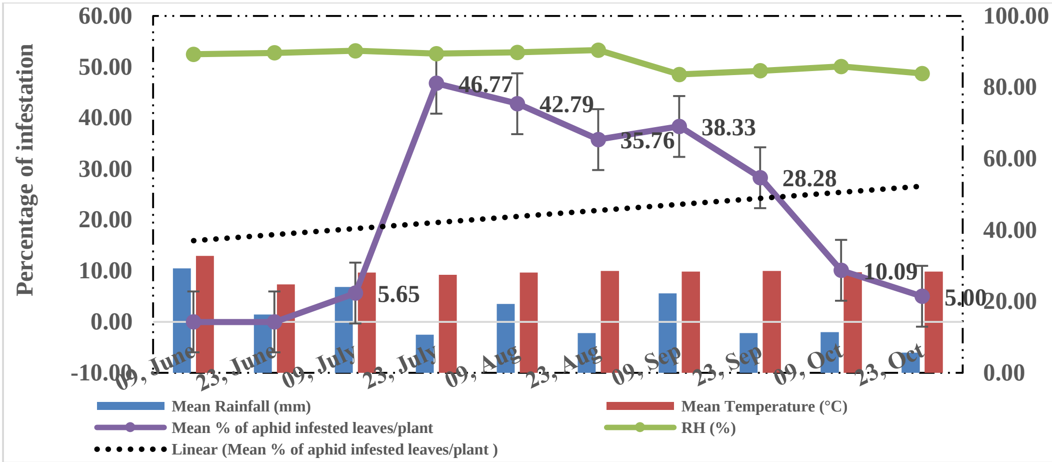


Figure 4.3.1.16 (a) Seasonal mean percentage of aphid infested leaves plant^{-1} on okra in jhum field at Bandarban during 2016.

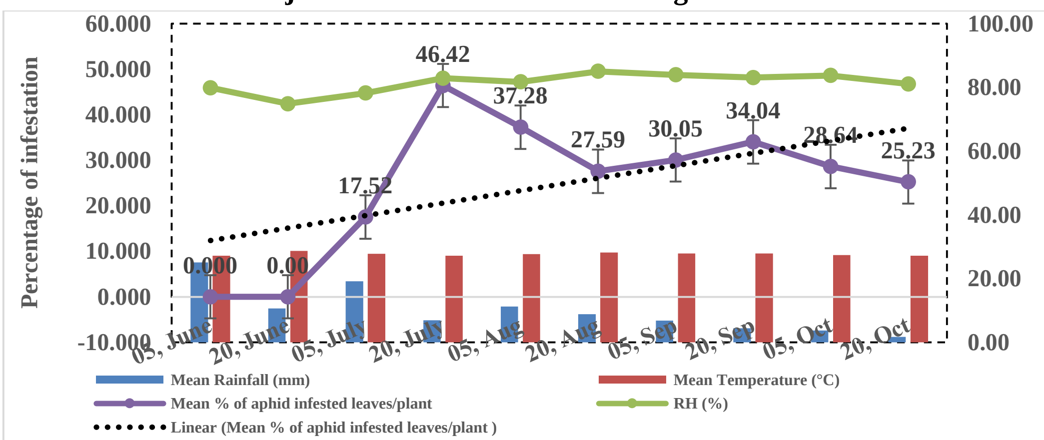


Figure 4.3.1.16 (b) Seasonal mean percentage of aphid infested leaves plant^{-1} on okra in jhum field at Rangamati during 2016.

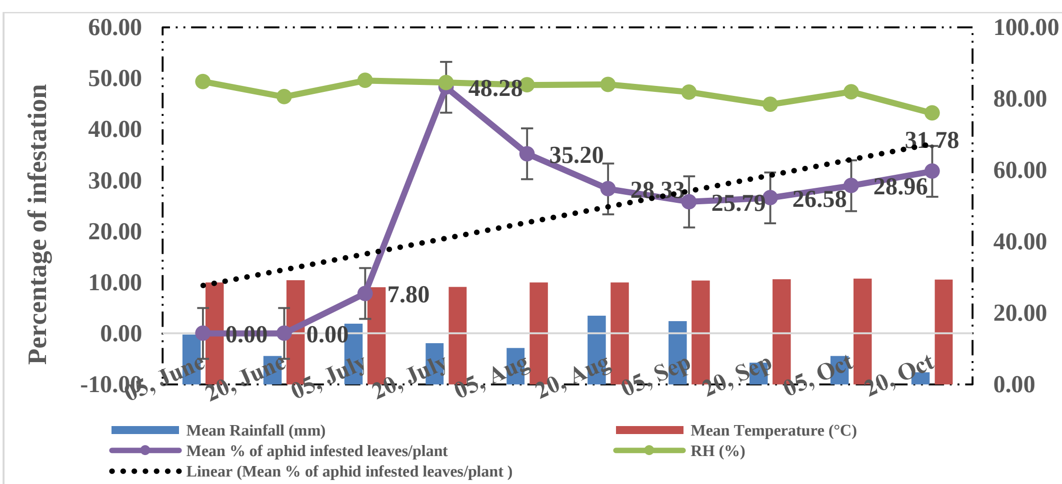


Figure 4.3.1.16 (c) Seasonal mean percentage of aphid infested leaves plant^{-1} on okra in jhum field at Khagrachari during 2016.

4.3.1.17 Dynamics of jassid infestation on okra in jhum field

During the year 2016, infestation levels of jassid attacking okra leaves at all the hill districts are shown in Figure 4.3.1.17 (a, b and c).

Figures revealed that the percent of jassid infested leaves plant^{-1} were started 50 days later after emerging okra plant in jhum field with an initial infestation of 4.23, 3.18 and 2.56 at Rangamati, Khagrachari and Bandarban, respectively during 1st and 2nd week of July. Then infestation of jassid leaf^{-1} was regularly augmented and got maximum of 27.78%, 24.74% and 26.18% for the period of 3rd and 4th week of July with decreasing rainfall and increasing relative humidity at Khagrachari, Rangamati and Bandarban, harmoniously.

With leisurely increasing of rainfall and temperature during the end of July to 1st week of September infestation declined normally and then slightly increased, and remain more or less fixed number up to end of the crop season at Khagrachari. Whereas, at Rangamati and Bandarban percent of infestation slowly dropped up to the end of 1st and 4th week of September independently and then increased infestation comparatively higher percent with lower rainfall at the later stage of the crop. Among the three hill districts rate of jassid infested leaves plant^{-1} were similar observed on okra in jhum fields. The overall trend of percent infestation of jassid leaf^{-1} during 2016 with seasonal incidence throughout the okra crop was undoubtedly positive linear at all experimental jhum field of Bandarban, Rangamati and Khagrachari.

4.3.1.18 Dynamics of whitefly infestation on okra in jhum field

During the year 2016, infestation levels of whitefly attacking okra leaves at all the hill districts are shown in Figure 4.3.1.18 (a, b and c). Figures revealed that percent of whitefly infested leaves plant^{-1} were started 80 days later after emerging okra plant in jhum field with an initial infestation of 0.26, and 1.16 at Rangamati and Bandarban, correspondingly during the end of 3rd and 4th week of August. Whereas, at Khagrachari the preliminary infestation started fifteen days earlier than other two hill region and reached the peak of 3.90 during the end of 3rd week of August. Then with slightly increasing of rainfall the infestation percent decreased slowly up to 3rd week of September and continue with slightly increasing infestation at the later stage of the crop with lower rainfall and temperature. After early infestation, it gradually increased and reached the maximum of 3.00 and 4.12 during the 4th week of September and the end of the 3rd week of October at Bandarban and Rangamati.

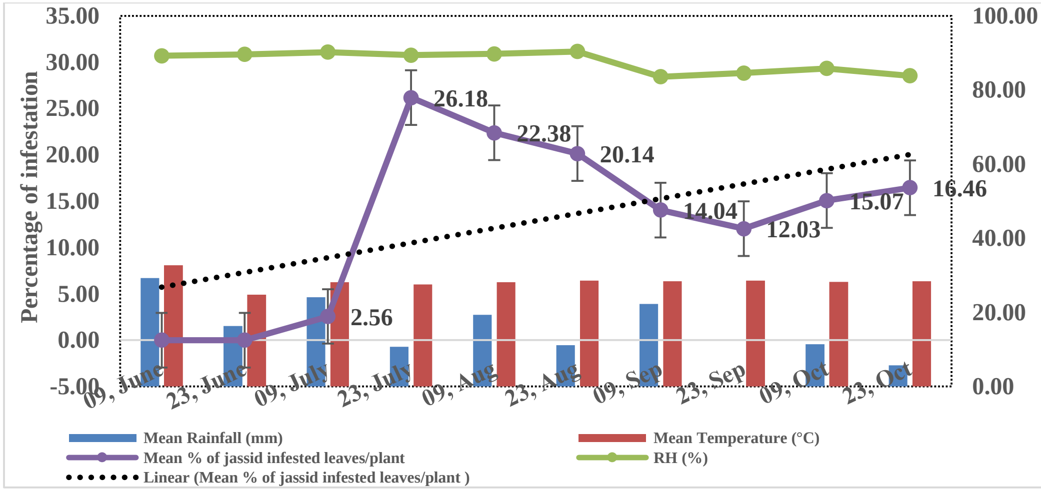


Figure 4.3.1.17 (a) Seasonal mean percentage of jassid infested leaves plant^{-1} on okra in jhum field at Bandarban during 2016.

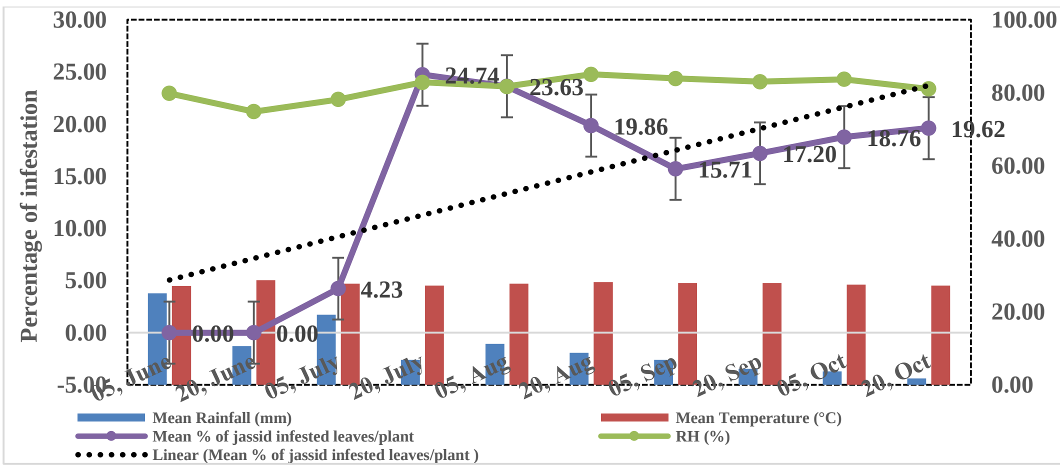


Figure 4.3.1.17 (b) Seasonal mean percentage of jassid infested leaves plant^{-1} on okra in jhum field at Rangamati during 2016.

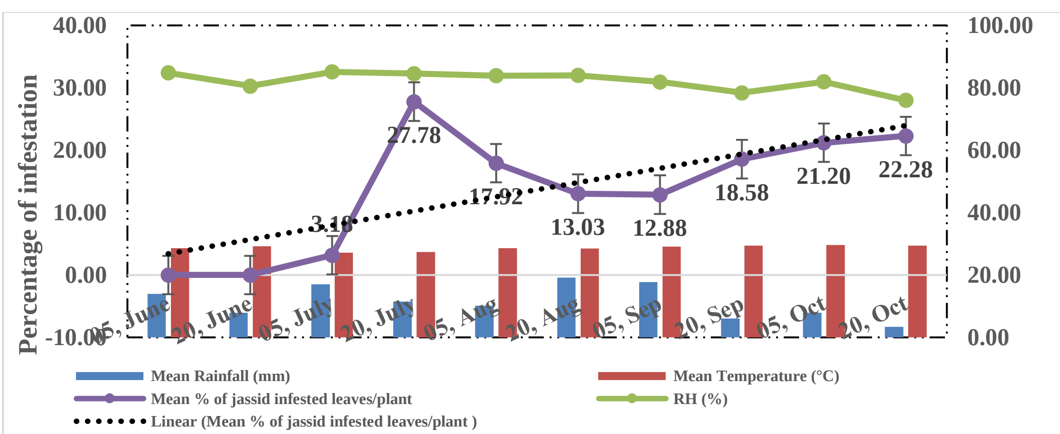


Figure 4.3.1.17 (c) Seasonal mean percentage of jassid infested leaves plant^{-1} on okra in jhum field at Khagrachari during 2016.

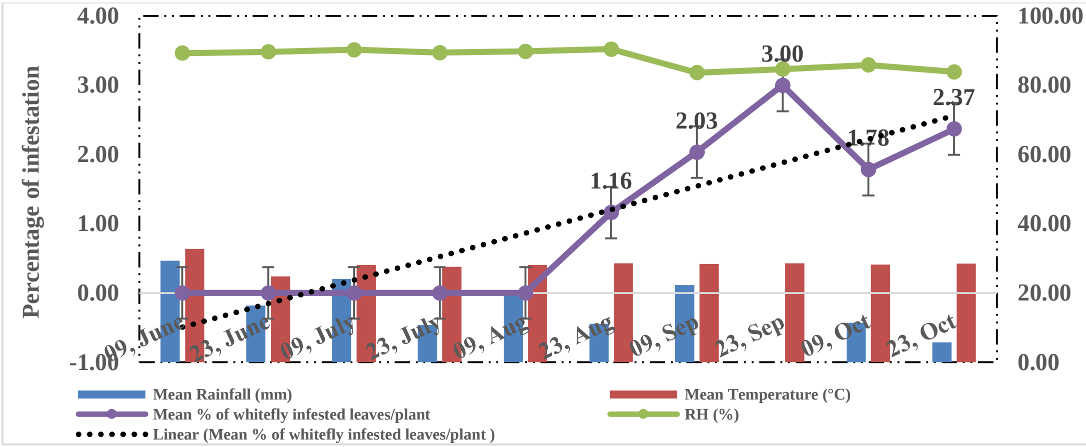


Figure 4.3.1.18 (a) Seasonal mean percentage of whitefly infested leaves plant^{-1} on okra in jhum field at Bandarban during 2016.

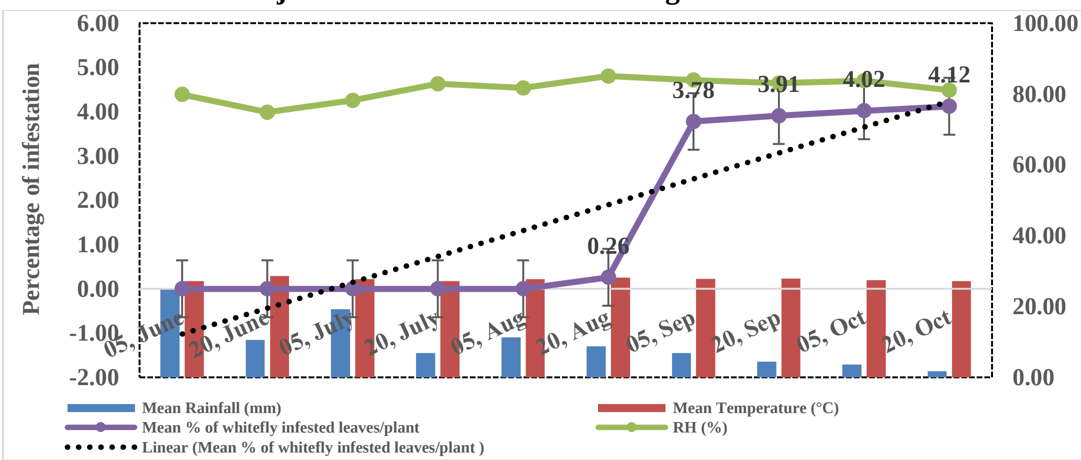


Figure 4.3.1.18 (b) Seasonal mean percentage of whitefly infested leaves plant^{-1} on okra in jhum field at Rangamati during 2016.

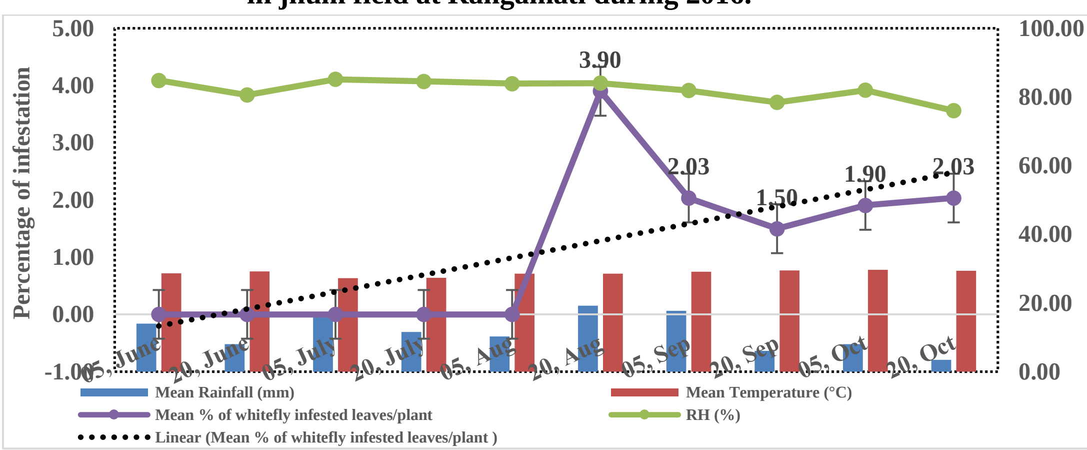


Figure 4.3.1.18 (c) Seasonal mean percentage of whitefly infested leaves plant^{-1} on okra in jhum field at Khagrachari during 2016.

With certain increasing of rainfall at Bandarban infestation shrink but once more gained the infestation rate at the end of the jhum season. Nevertheless, with decreasing mean rainfall and temperature after 3rd week of August whitefly infested leaves plant^{-1} steadily advanced at the matured stage of okra crop at Rangamati. The general trend of mean percent infestation of whitefly leaf^{-1} during 2016 with seasonal incidence on all over the okra crop was indeed positively linear. Among the sucking pests on okra, whitefly infestation was much lower than both aphid and jassid at all experimental jhum fields of Bandarban, Rangamati and Khagrachari.

4.3.1.19 Dynamics of okra shoot and fruit borer (OSFB) infestation on okra in jhum field

During the year 2016, infestation levels of OSFB attacking okra fruits plant^{-1} at all hill districts are shown in Figure 4.3.1.19 (a, b and c).

Figures revealed that mean percentage of OSFB infested fruits/plant were started just after fruit setting on okra plant in jhum field with few initial infestations of 0.96, 0.90 and 0.77 at Bandarban, Rangamati and Khagrachari, respectively during 2nd and 1st week of August. Infestation gradually increased and reached the maximum of 3.52 and 2.48 during 1st week of October at Rangamati and Khagrachari respectively, however, at Bandarban infestation fluctuate and reached the highest 2.40 for the period of 4th week of October. Then infestation percent declined gently at the later stage of okra fruits in all experimental jhum fields of the three hill districts. A general trend of mean percent infestation of OSFB attacking okra fruits plant^{-1} during 2016 with seasonal incidence all over the okra crop growth was simply positively linear and caused no substantial loss at all experimental jhum fields.

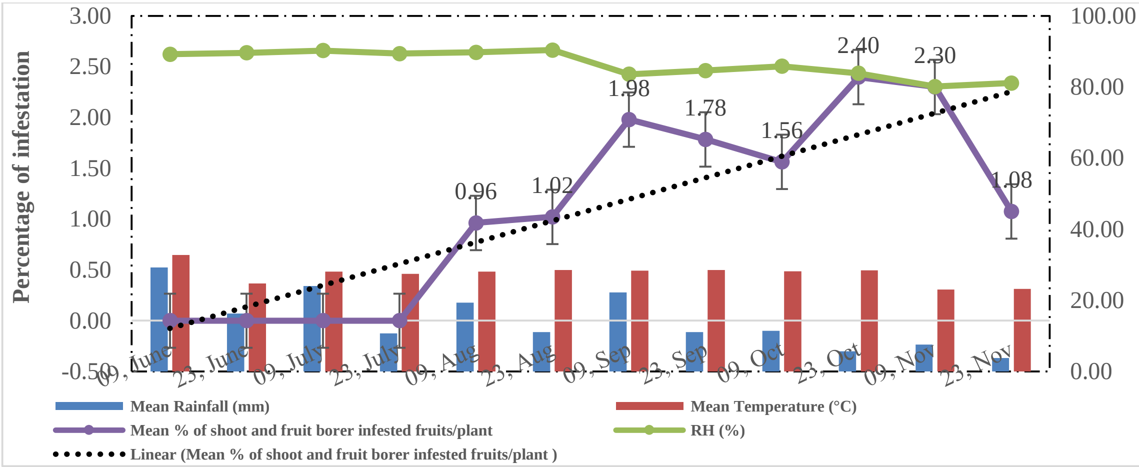


Figure 4.3.1.19 (a) Seasonal mean percentage of shoot and fruit borer infested fruits plant^{-1} on okra in jhum field at Bandarban during 2016.

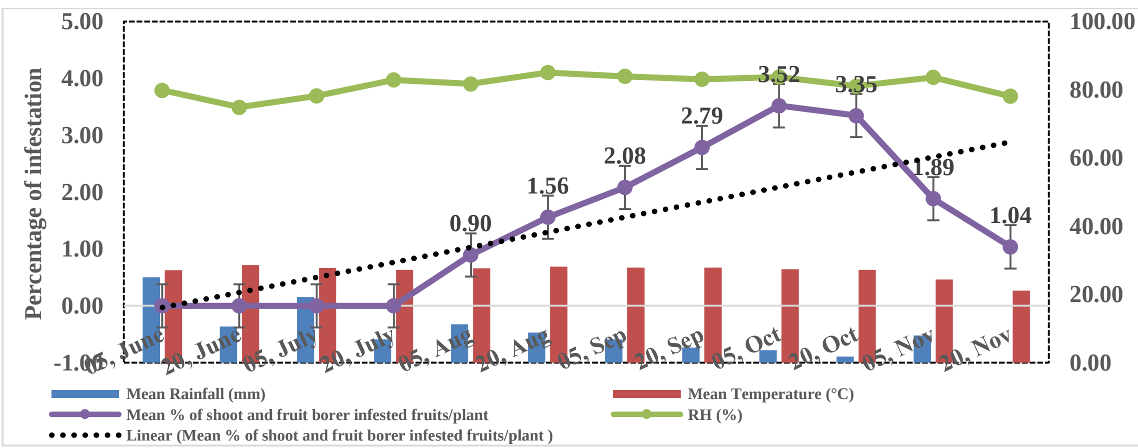


Figure 4.3.1.19 (b) Seasonal mean percentage of shoot and fruit borer infested fruits plant^{-1} on okra in jhum field at Rangamati during 2016.

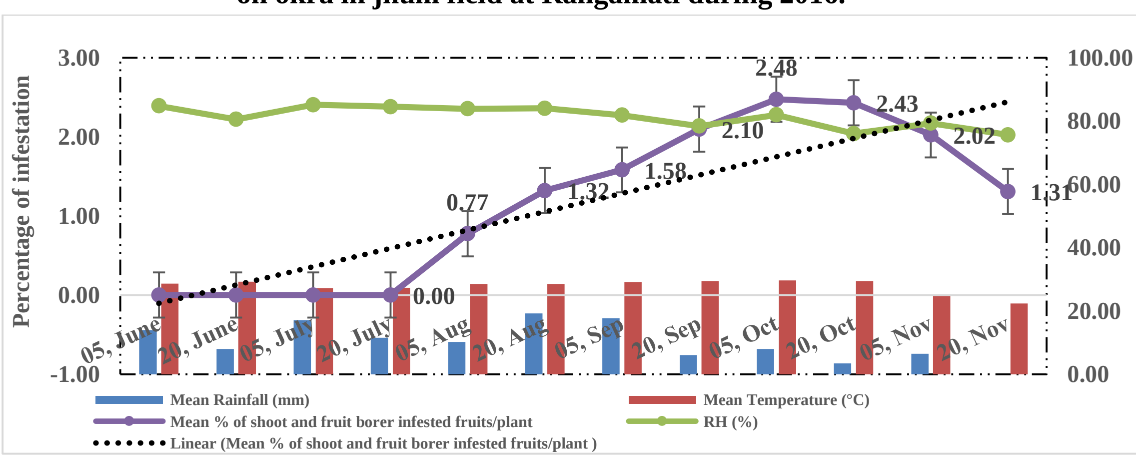


Figure 4.3.1.19 (c) Seasonal mean percentage of shoot and fruit borer infested fruits plant^{-1} on okra in jhum field at Khagrachari during 2016.

4.3.1.20 Dynamics of aphid infestation on sesame in jhum field

During the year 2016, infestation levels of aphid attacking sesame twigs at all the hill districts are shown in Figure 4.3.1.20 (a, b and c). Figures revealed that the mean percentage of aphid infested twigs plant^{-1} were started about 100 days later after emerging sesame plant in jhum field with initial very limited twig infestation during the end of the month of August.

Figures revealed that the percent of aphid infested twigs plant^{-1} were started 100 days later after emerging sesame plant in jhum field with initial very limited twig infestation during the end of August. With decreasing rainfall and temperature infestation increased very slowly and reached the maximum of 17.44, 12.96 and 8.93 at the end of the crop when pod mature enough for harvest at Bandarban, Rangamati and Khagrachari, respectively. The hill sesame variety is characterized by vigorous plant growth with plentiful branches in addition to long-duration for harvesting the pod. Aphid may prefer the pod with bearing twig for sucking sap from them. Aphid infestation rate increased with increasing their flowering and pod formation in sesame plant.

It was clear enough common trend of percent infestation of aphid/twig during 2016 with seasonal incidence throughout the sesame crop were positive linear at all experimental jhum field of Bandarban, Rangamati and Khagrachari.

4.3.1.21 Dynamics of jassid infestation on sesame in jhum field

During the year 2016, infestation levels of jassid attacking sesame leaves at all hill districts are shown in Figure 4.3.1.21 (a, b and c).

Figures revealed that the percent of jassid infested leaves plant^{-1} were started about 100 days later after emerging sesame plant in jhum field with preliminary very limited leaves infestation during the end of August. With declining mean rainfall and temperature jassid infestation very slowly increased and grasped maximum of 11.96, 11.60 and 11.49 during 2nd and 1st week of November at Bandarban, Rangamati and Khagrachari, correspondingly.

Similar positive linear infestation tendency observed at all the hill experimental fields, nevertheless percent of jassid infestation are much lower than aphid infestation on the same crop in the jhum field at all hill districts of Bangladesh.

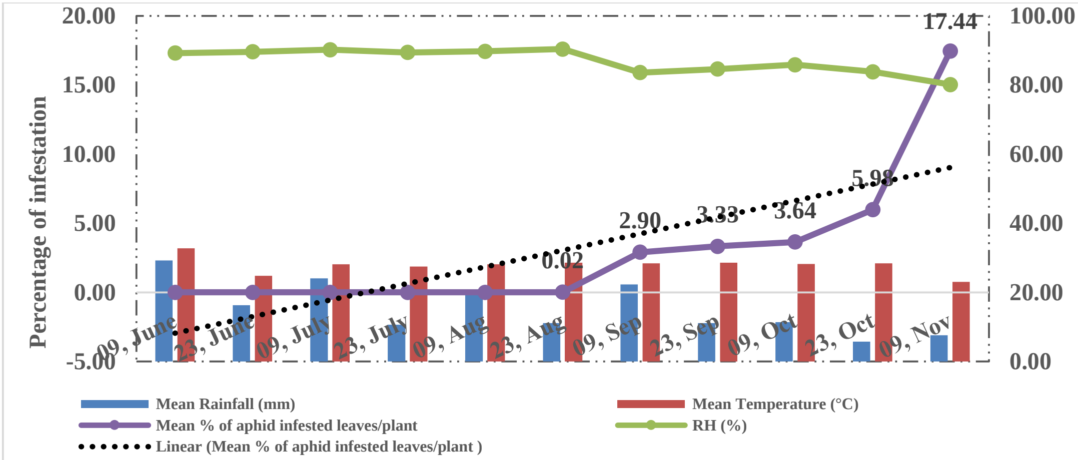


Figure 4.3.1.20 (a) Seasonal mean percentage of aphid infested leaves plant^{-1} on sesame in jhum field at Bandarban during 2016.

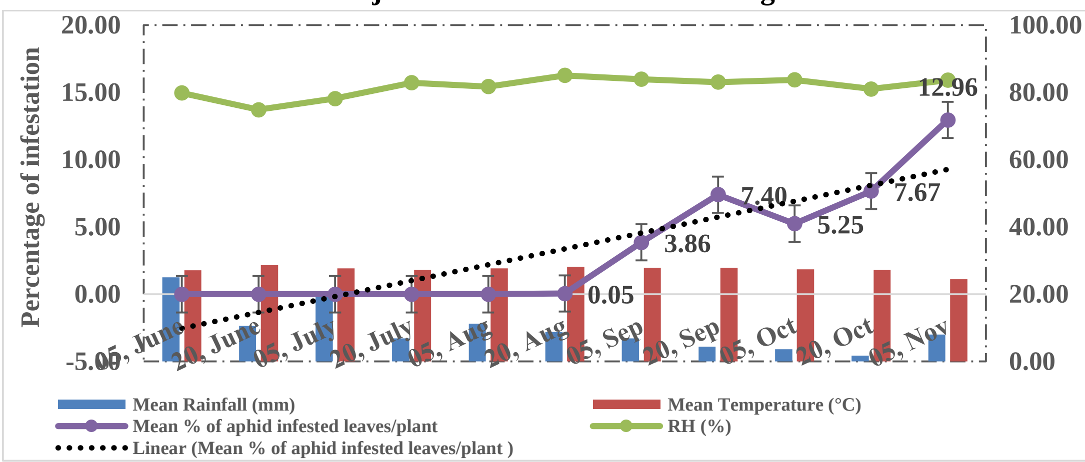


Figure 4.3.1.20 (b) Seasonal mean percentage of aphid infested leaves plant^{-1} on sesame in jhum field at Rangamati during 2016.

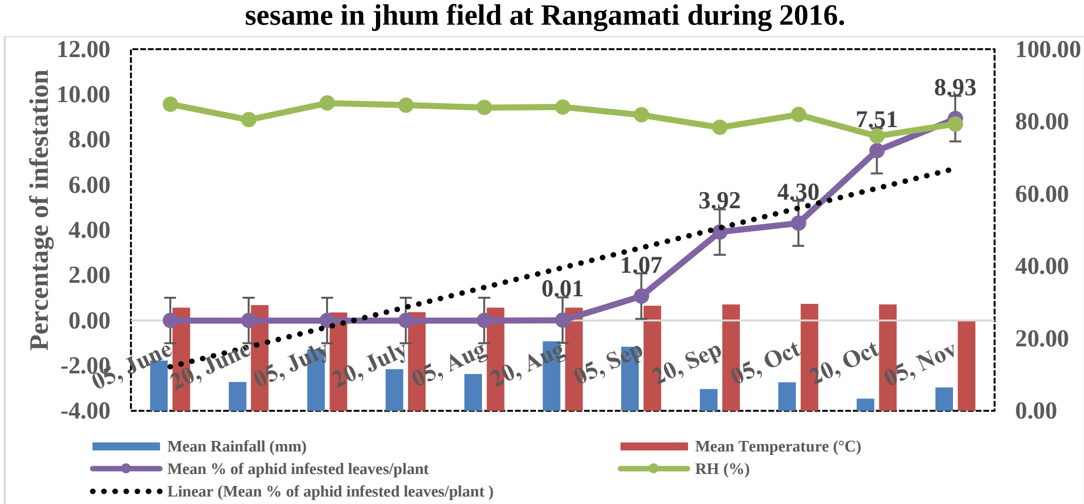


Figure 4.3.1.20 (c) Seasonal mean percentage of aphid infested leaves plant^{-1} on sesame in jhum field at Khagrachari during 2016.

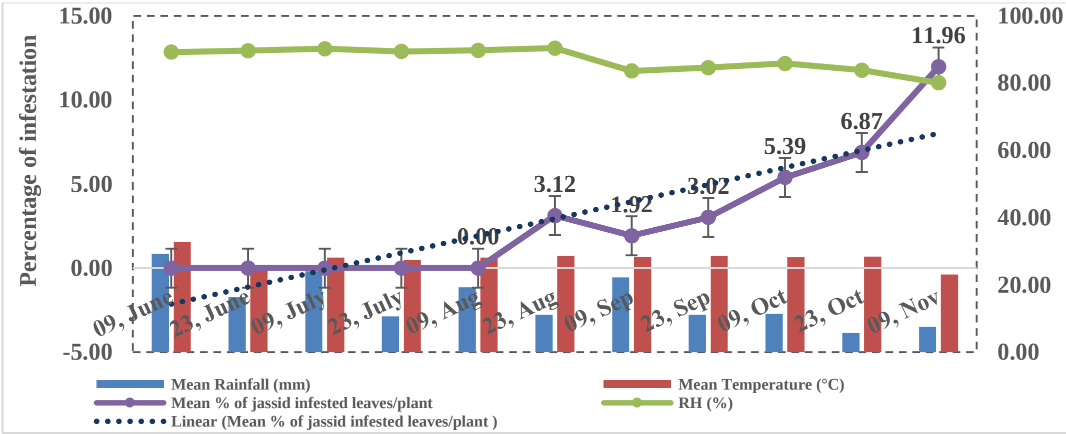


Figure 4.3.1.21 (a) Seasonal mean percentage of jassid infested leaves plant^{-1} on sesame in jhum field at Bandarban during 2016.

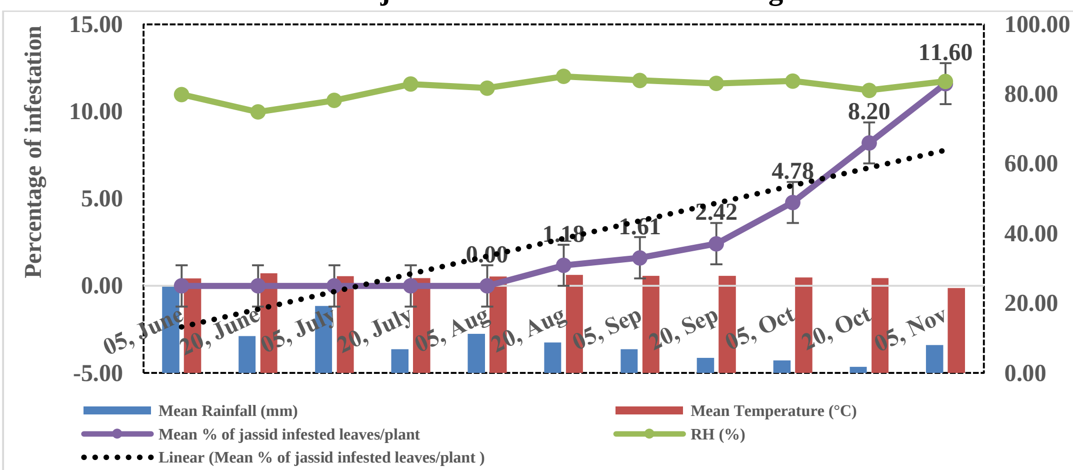


Figure 4.3.1.21 (b) Seasonal mean percentage of jassid infested leaves plant^{-1} on sesame in jhum field at Rangamati during 2016.

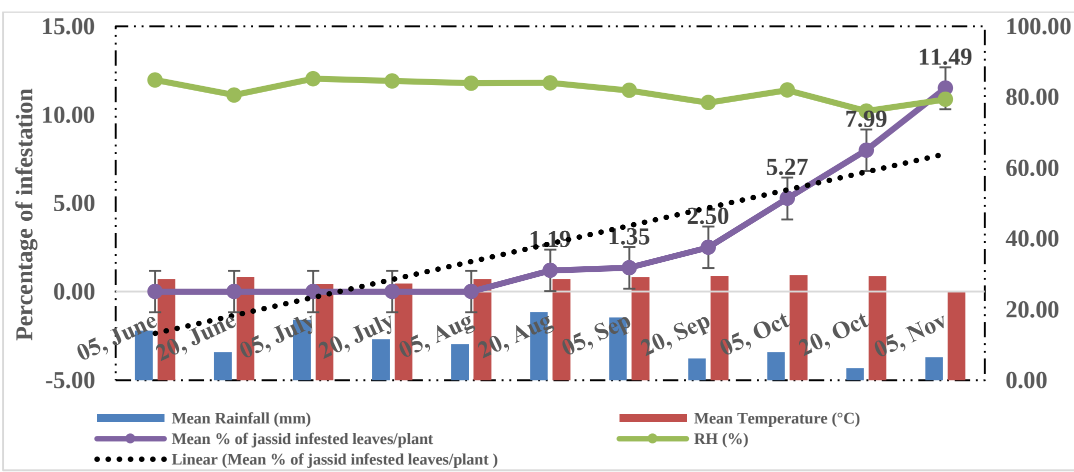


Figure 4.3.1.21 (c) Seasonal mean percentage of jassid infested leaves plant^{-1} on sesame in jhum field at Khagrachari during 2016.

4.3.1.22 Dynamics of flea beetle infestation on sesame in jhum field

During the year 2016, infestation levels of flea beetle attacking sesame leaves at all hilly districts are shown in Figure 4.3.1.22 (a, b and c). Figures revealed that the rate of flea beetle-infested leaves plant^{-1} were started about 85-100 days later after rising sesame plant in jhum field with preliminary very limited leaves infestation observed during August. Then the percent of infestation severely increased and reached the maximum of 9.67, 7.68 and 16.99 during 1st and 2nd week of September at Rangamati, Khagrachari and Bandarban, respectively. With declining rainfall and temperature flea beetle infestation develop very slowly at Khagrachari and continued the lower infestation at the later stage of the crop season. Furthermore, in both experimental fields of Bandarban and Rangamati, infestation decreased rapidly and the maintained infestation more or less static up to end of the 4th and 3rd week of October. After the end of October, the percent infestation abruptly declined due to mature stage of sesame plant at all experimental fields of hill districts. General trends of mean percent infestation of leaf-feeding beetle were slightly positive linear propensity observed at Bandarban, Rangamati and Khagrachari.

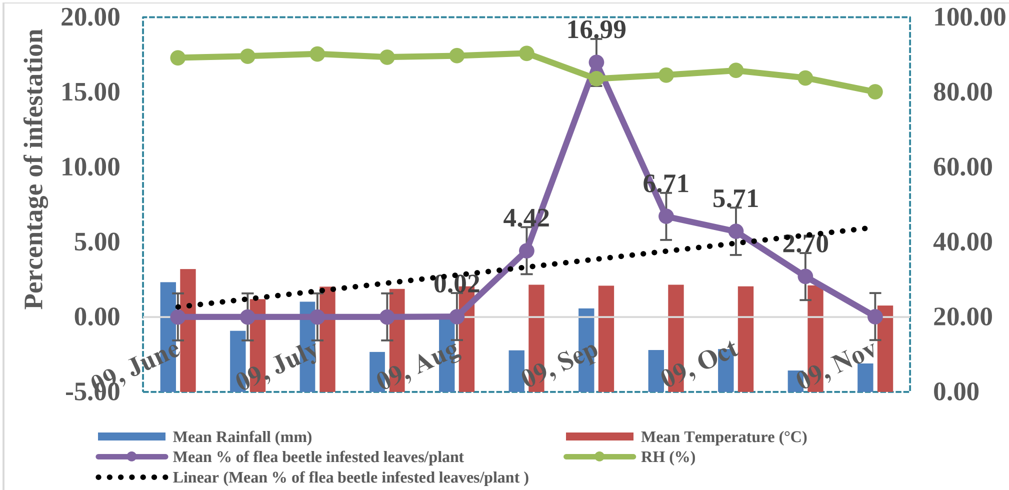


Figure 4.3.1.22 (a) Seasonal mean percentage of flea beetle infested leaves plant^{-1} on sesame in jhum field at Bandarban during 2016.

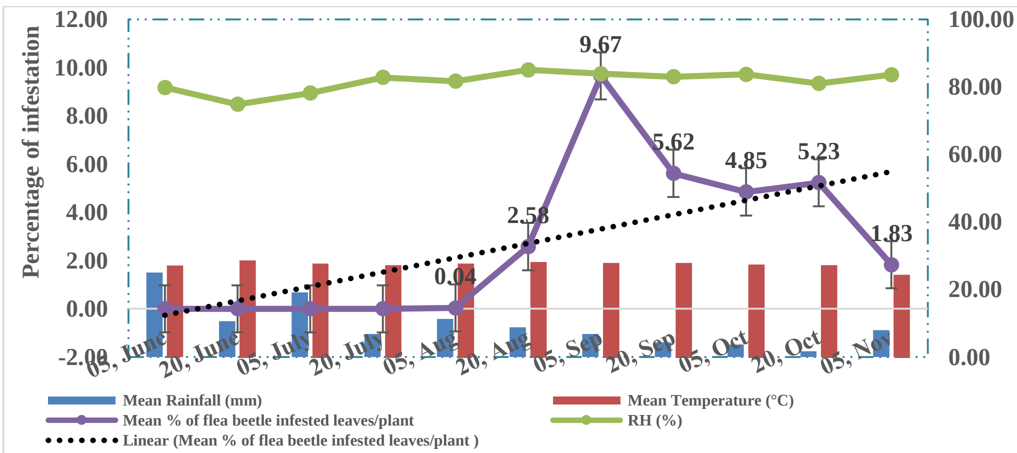


Figure 4.3.1.22 (b) Seasonal mean percentage of flea beetle infested leaves plant^{-1} on sesame in jhum field at Rangamati during 2016.

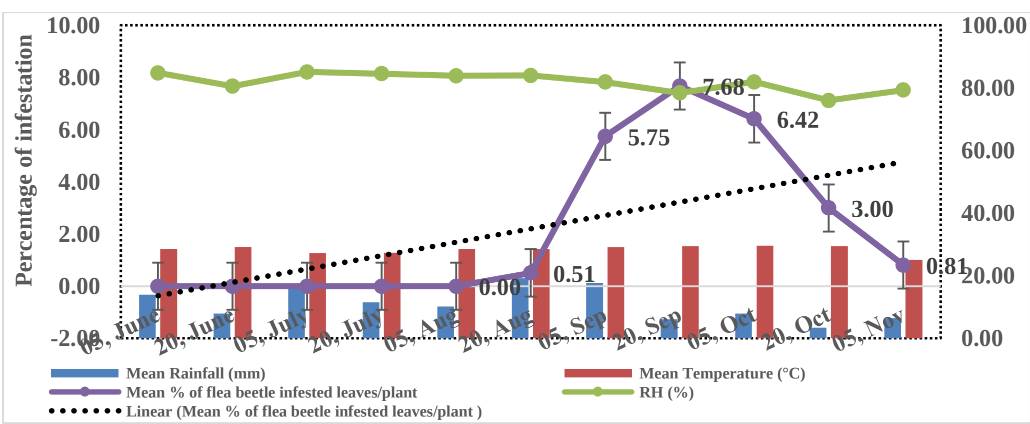


Figure 4.3.1.22 (c) Seasonal mean percentage of flea beetle infested leaves plant^{-1} on sesame in jhum field at Khagrachari during 2016.

4.3.1.23 Dynamics of leaf webber infestation on sesame in jhum field

During the year 2016, infestation levels of leaf webber attacking sesame leaves at all hill districts are presented in Figure 4.3.1.23 (a, b and c). Figures revealed that the percent of leaf Webber infested leaves plant^{-1} were started about 55 to 70 days later after sesame plant raised in jhum field with initial very low leavel of infestation during the month of July.

With increasing temperature percent infestation sharply increased and reached the peak of 33.82, 19.32 and 20.81 during the 3rd and 4th week of September at Khagrachari, Rangamati and Bandarban, correspondingly. Among three experimental hill districts, leaf-webber infested leaves plant^{-1} were comparatively higher resulted that maximum leaf damage at Khagrachari however, similar percent infestation revealed at Bandarban and Rangamati.

The peak of percent infestation suddenly declined and the caterpillar disappeared approximately 4th week of September with decreasing mean rainfall and temperature at all experimental jhum fields of Khagrachari, Rangamati and Bandarban. Among the leaf damaging insect leaf webber caterpillar infestation was much higher and destructive then the leaf flea beetle, hawk-moth. Common trends of mean percent infestation during 2016 with seasonal incidence throughout the sesame crop were parallel linear at all experimental jhum field.

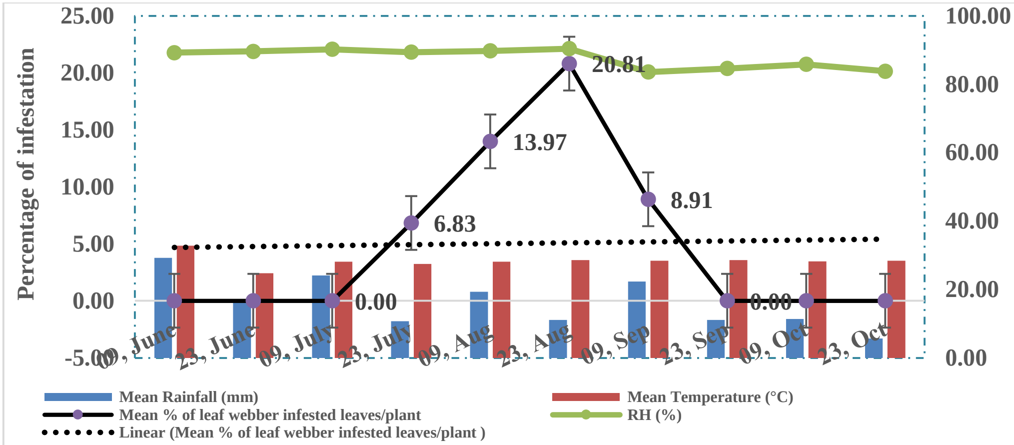


Figure 4.2.1.23 (a) Seasonal mean percentage of leaf webber infested leaves plant^{-1} on sesame in jhum field at Bandarban during 2016.

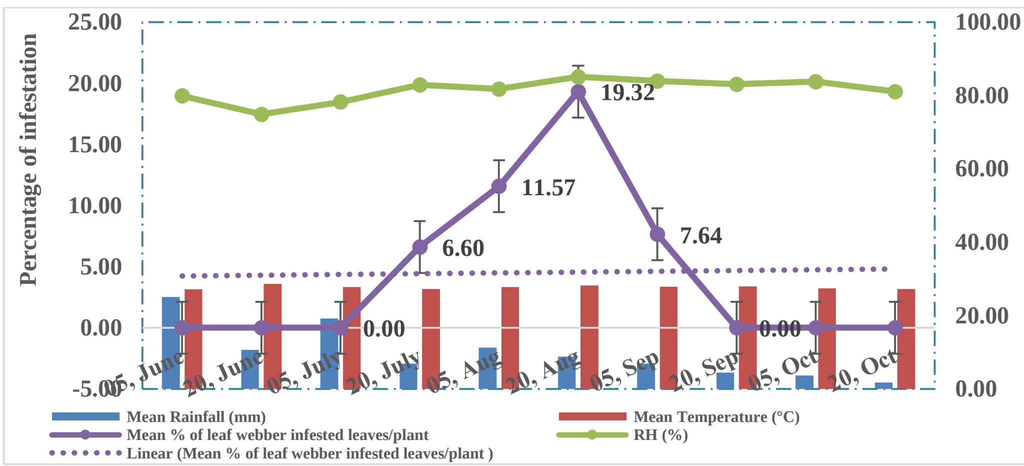


Figure 4.3.1.23 (b) Seasonal mean percentage of leaf webber infested leaves plant^{-1} on sesame in jhum field at Rangamati during 2016.

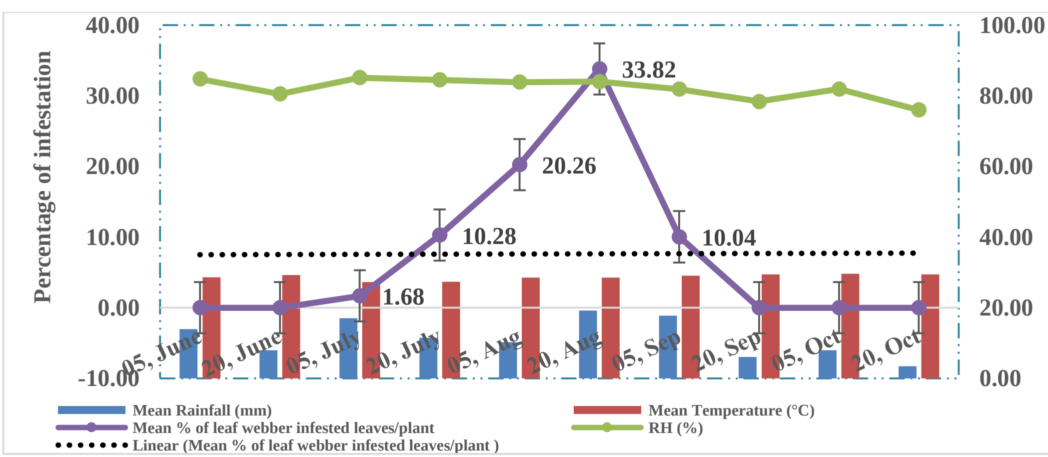


Figure 4.3.1.23 (c): Seasonal mean percentage of leaf webber infested leaves plant^{-1} on sesame in jhum field at Khagrachari during 2016.

4.3.1.24 Dynamics of pod borer infestation on sesame in jhum field

During the year 2016, infestation levels of pod borer attacking sesame pods twig^{-1} at all the hill districts are presented in Figure 4.3.1.24 (a, b and c).

Figures revealed that mean percentage of pod borer infested pods twig^{-1} were started later stage i.e., pod formation stage in jhum field during 1st and 2nd week of October at Bandarban, Khagrachari and Rangamati. Therefore pod borer infestation confined in between one month of infesting and reached the highest peak of 2.14, 2.13 and 1.12 during the end of 3rd and 4th week of October at Khagrachari, Rangamati and Bandarban individually.

The percent of infestation during 2016 with seasonal incidence throughout the sesame crop were not enough to damage the pod, consequently no impact on the yield of a sesame seed at all the three experimental fields of hill districts.

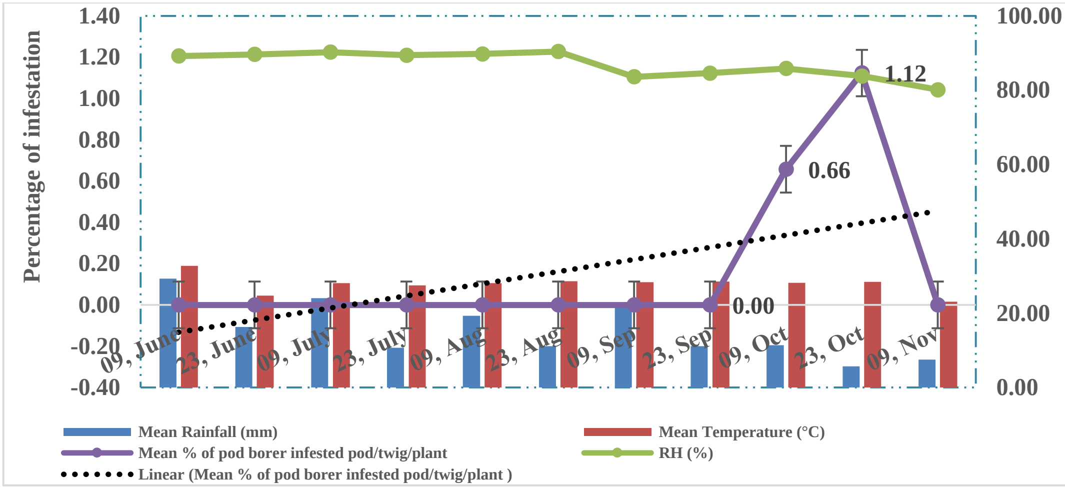


Figure 4.3.1.24 (a) Seasonal mean percentage of pod borer infested pod twig^{-1}plant^{-1} on sesame in jhum field at Bandarban during 2016.

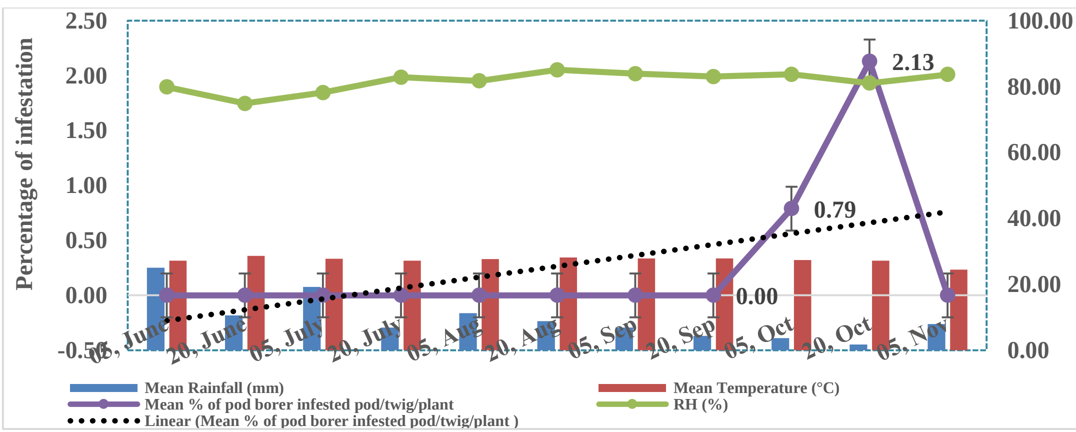


Figure 4.3.1.24 (b) Seasonal mean percentage of pod borer infested pod twig^{-1}plant^{-1} on sesame in jhum field at Rangamati during 2016.

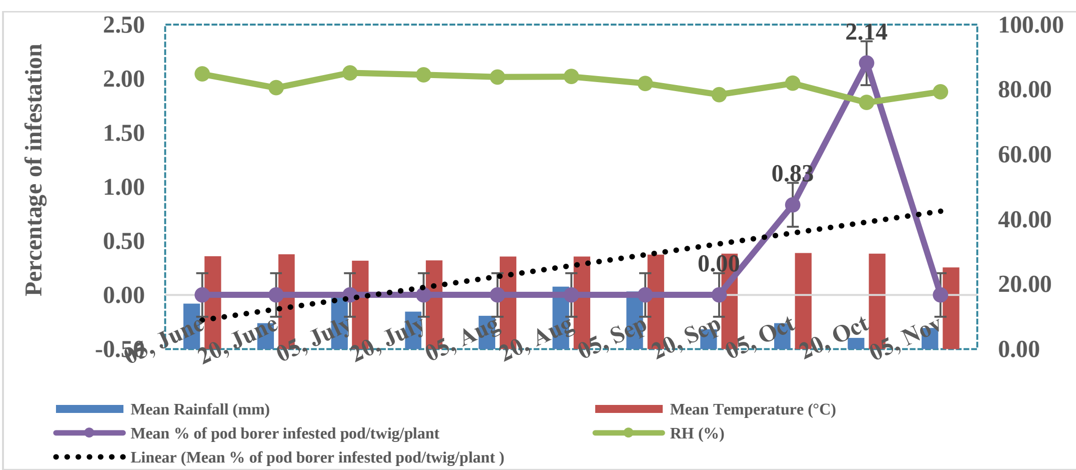


Figure 4.3.1.24 (c) Seasonal mean percentage of pod borer infested pod twig^{-1}plant^{-1} on sesame in jhum field at Khagrachari during 2016.

4.3.1.25 Dynamics of pentatomid bug infestation on sesame in jhum field

During the year 2016, infestation levels of pentatomid bug attacking sesame leaves at all hill districts are given in Figure 4.3.1.25 (a, b and c).

Mean percent pentatomid bug during 2016 with seasonal incidence throughout the marpha crops were significant enough to damage the leaves at all the three experimental fields of hill districts. Figures revealed that mean percentage of pentatomid bug-infested leaves plant^{-1} started very slowly at the 1st week of July at Rangamati and Khagrachari whereas, at Bandarban started at mid of the 2nd week of July with the similar trend but 15 days later of sesame crop at jhum fields. Thereafter pentatomid bug infestation was progressively increased and reached a maximum of 29.66 and 25.44 during the end of 3rd week of August at Rangamati and Khagrachari, individually. However the infestation percentage reached a peak of 22.48 on the 2nd week of August at Bandarban.

Among the three experimental fields, comparatively higher infestation were observed at Rangamati. With the decreasing of mean rainfall and temperature, infestation rate declined abstemiously at all experimental fields of sesame at all hill districts and at later stage of the crop its percent infestation were very scarce on leaves plant^{-1}. Figure 4.3.1.11 (a, b and c) and 4.3.1.25 (a, b and c) revealed that pentatomid bug prefers marpha leaves more for then sesame leaves.

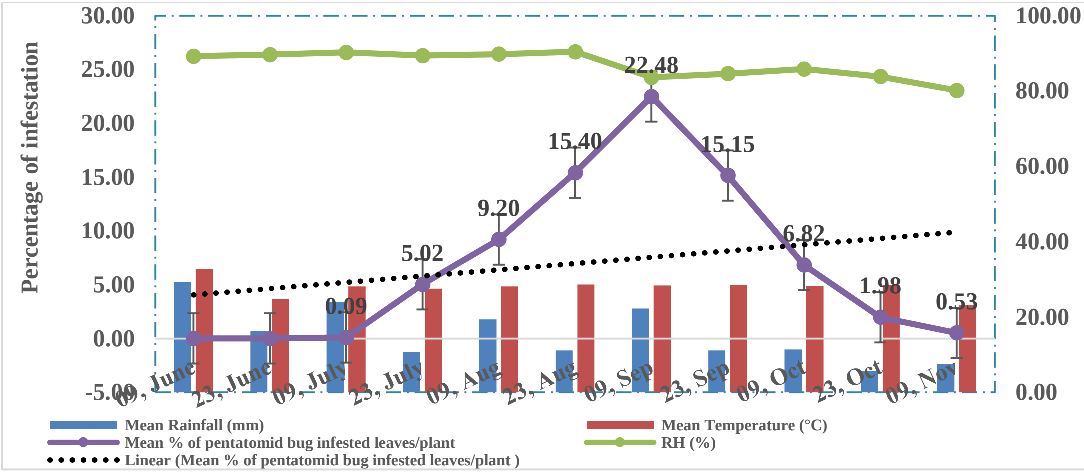


Figure 4.3.1.25 (a) Seasonal mean percentage of pentatomid bug infested leaves plant^{-1} on sesame in jhum field at Bandarban during 2016.

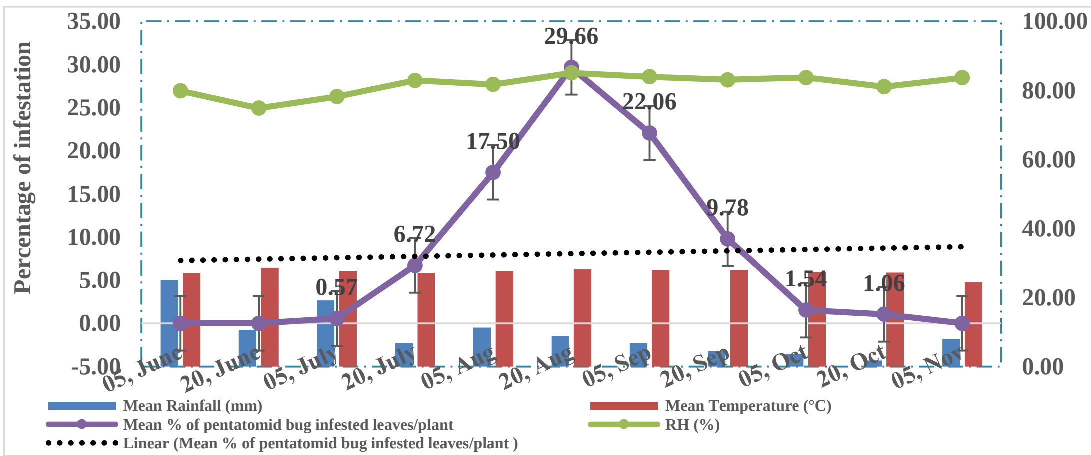


Figure 4.3.1.25 (b) Seasonal mean percentage of pentatomid bug infested leaves plant^{-1} on sesame in jhum field at Rangamati during 2016.

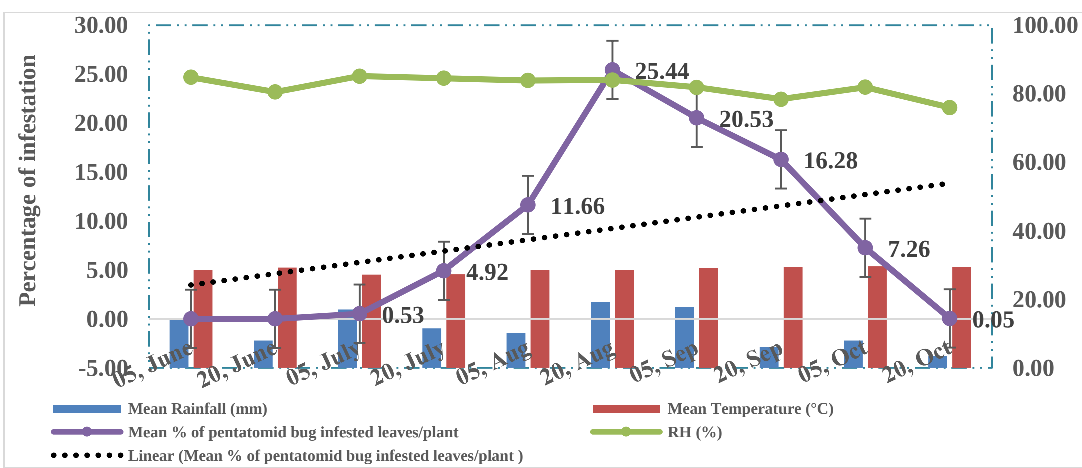


Figure 4.3.1.25 (c) Seasonal mean percentage of pentatomid bug infested leaves plant^{-1} on sesame in jhum field at Khagrachari during 2016.

4.3.1.26 Dynamics of hawk-moth infestation on sesame in jhum field

During the year 2016, infestation levels of hawk-moth attacking sesame leaves at all hilly districts are presented in Figure 4.3.1.26 (a, b and c). Figures revealed that the percent infestation of hawk-moth (leaves plant^{-1}) started during the period of 1st and 2nd week of August at Rangamati, Khagrachari and Bandarban. The overall percentage of hawk-moth infestation confined during the month of August and in addition, reached a maximum of 4.70, 4.58 and 4.57 for the duration of 4th and end of 3rd week of the same month at Bandarban, Rangamati and Khagrachari, in that order.

With decreasing of temperature after the month of August hawk-moth were disappeared from all experimental fields of three hill districts. At jhum fields at a time different crops cultivated in the slope of the hill after burning the previous weeds and other bushes when the hawk-moth infestation was much less and insignificant than the sesame monoculture in the plane fields at other regions of Bangladesh.

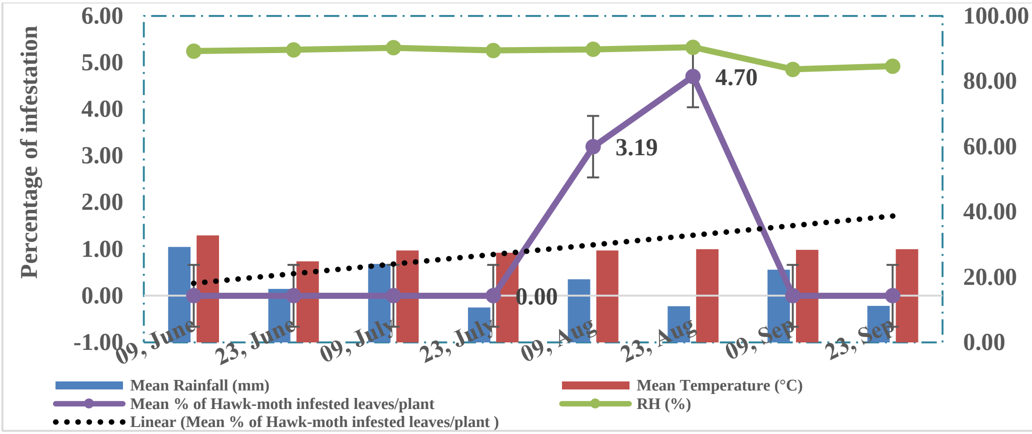


Figure 4.3.1.26 (a): Seasonal mean percentage of hawk-moth infested leaves plant^{-1} on sesame in jhum field at Bandarban during 2016.

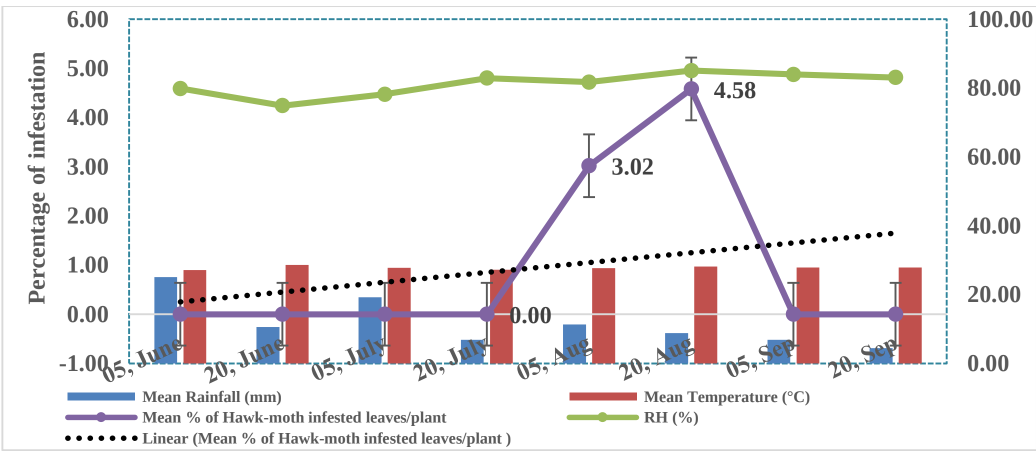


Figure 4.3.1.26 (b) Seasonal mean percentage of hawk-moth infested leaves plant^{-1} on sesame in jhum field at Rangamati during 2016.

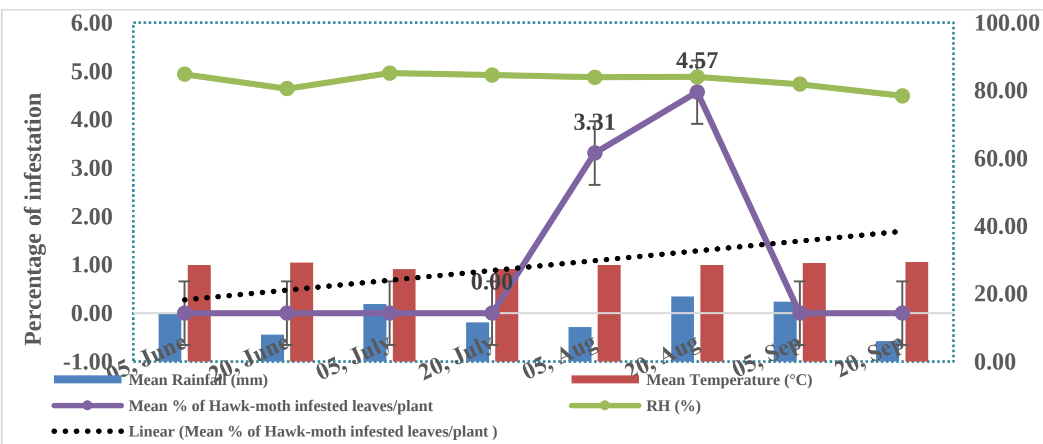


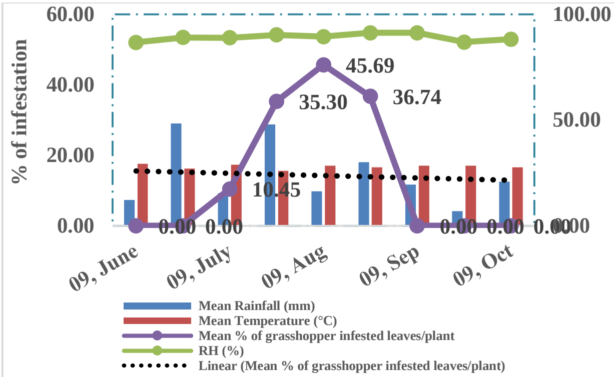
Figure 4.3.1.26 (c) Seasonal mean percentage of hawk-moth infested leaves plant^{-1} on sesame in jhum field at Khagrachari during 2016.

4.3.1.27 Dynamics of grasshopper infestation on maize in jhum field

During the year 2015 and 2016, population levels of grasshopper attacking maize at all hill districts are shown in Figure 4.3.1.27 (a, b and c) and 4.3.1.27 (d, e and f), respectively. Figure 4.3.1.27 (a, b and c) revealed that grasshopper infestation started from 1st and 2nd week of July after of maize plant arise from the ground at Rangamati, Khagrachari and Bandarban. During the year 2015, the initial infestation of grasshopper gradually increased on maize leaves plant^{-1} and reached the maximum of 54.74, 43.65 and 45.69 during the 1st and 2nd week of August at Khagrachari, Rangamati and Bandarban, correspondingly. Then the infestation decreased slowly and disappeared after the beginning month of September.

During the year 2016, Figure 4.3.1.27 (d, e and f) revealed that just around the 1st week of July, infestation of the grasshopper was not countable but at the end of the 3rd and 4th week of July significant number of leaves were damaged (73.96, 58.99 and 70.03) by grasshopper at Khagrachari, Rangamati and Bandarban, correspondingly. Percentage of grasshopper infestation maintain their devastation and reached a maximum level of 74.93 and 71.16 during the end of 3rd and 4th week of August at Khagrachari and Rangamati one to one.

Whereas a similar trend of infestation observed during initial infestation to the end of the month of August at Bandarban and infestation reached a peak (68.72) during 2nd week of August. Grasshopper infestation confined before or later 2nd week of July to end of the month of August at all the three experimental jhum fields during 2015 and 2016. The comparatively higher infestation was observed in 2016 than 2015, perhaps due to higher mean rainfall in 2015 during peak infestation which might suppress grasshopper population at all experimental jhum fields.



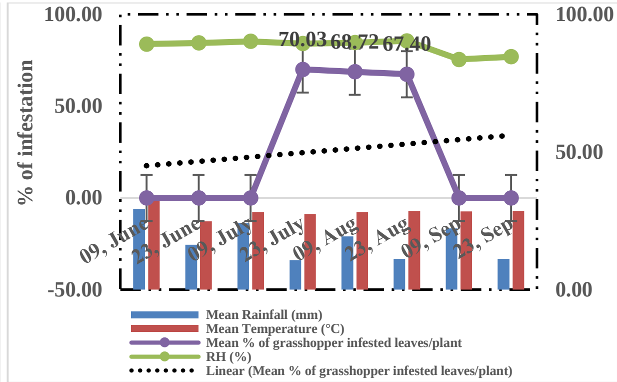
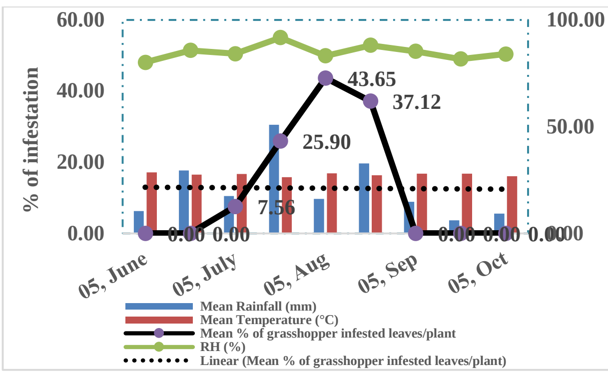


Figure 4.3.1.27 (a) Bandarban during 2015. **Figure 4.3.1.27 (d) Bandarban during 2016.**

Figure 4.3.1.27 (a & d) Seasonal grasshopper infested leaves plant^{-1} on maize in jhum field at Bandarban during 2015 and 2016.



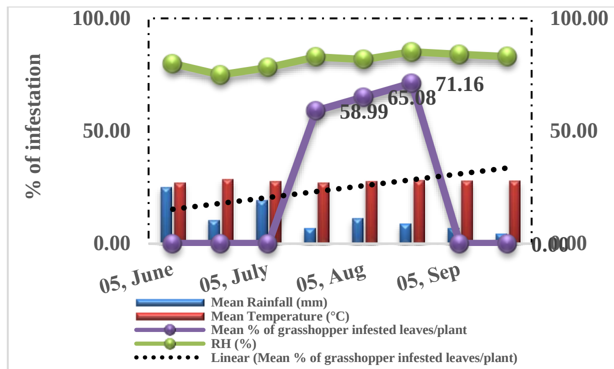
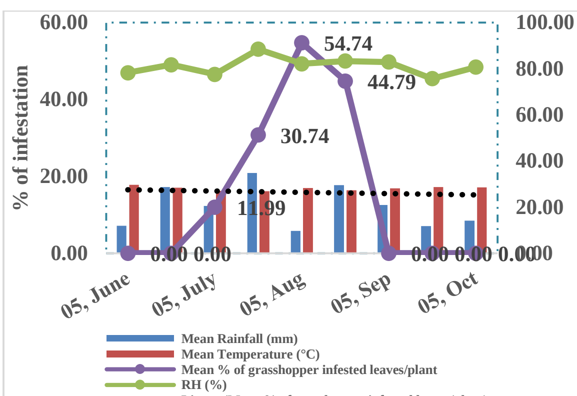


Figure 4.3.1.27 (b) Rangamati during 2015. **Figure 4.3.1.27 (e) Rangamati during 2016.**

Figure 4.3.1.27 (b & e) Seasonal grasshopper infested leaves plant^{-1} on maize in jhum field at Rangamati during 2015 and 2016.



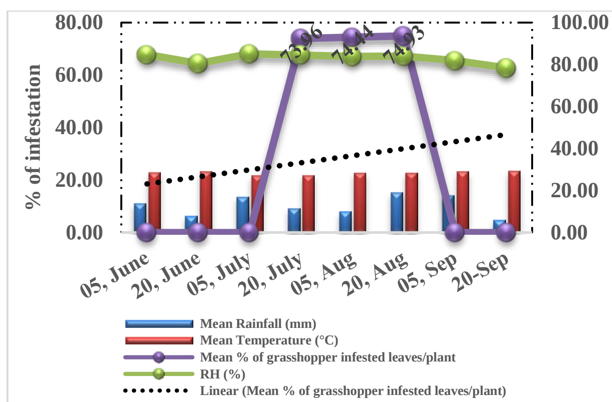


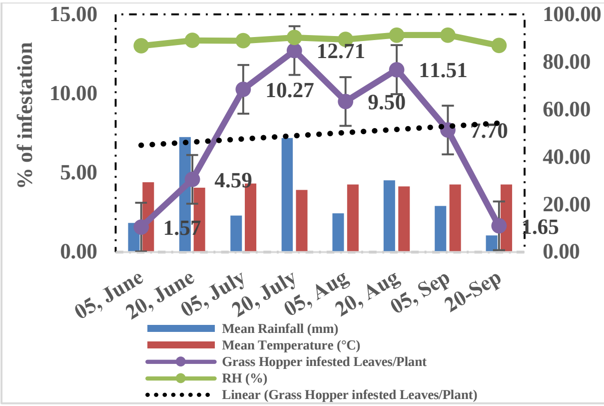
Figure 4.3.1.27 (c) at Khagrachari during 2015. **Figure 4.3.1.27 (f) at Khagrachari during 2016.**

Figure 4.3.1.27 (c & f): Seasonal grasshopper infested leaves plant^{-1} on maize in jhum field at Khagrachari during 2015 and 2016.

4.3.1.28 Dynamics of grasshopper infestation on rice in jhum field

During the year 2015 and 2016, population levels of grasshopper attacking rice at all hill districts are shown in Figure 4.3.1.28 (a, b and c) and 4.3.1.28 (d, e and f). Figures 4.3.1.28 (a, b and c) revealed that very limited percentage of grasshopper infestation started during 1st week of June after the rice plant arise from jhum fields at Rangamati, Khagrachari and Bandarban, respectively. During the year 2015, after initial infestation by grasshopper, gradually increased on rice (leaves plant^{-1}) and reached the maximum of 12.71, 9.71 and 7.34 during the end of 3rd week of July at Bandarban, Rangamati and Khagrachari, respectively. After peak percent infestation slightly declined and its damage to the leaves continued till 1st week of September.

During the year 2016, preliminary insignificant infestation started on the 1st week of July at Rangamati and Khagrachari whereas, at Bandarban significant initial infestation (5.92) was revealed during 2nd week of July. In comparison to the seasonal incident, previous year infestation starts and one month earlier than the year 2016. A similar percentage of infestation trend (2015) were observed throughout the rice season (2016) in the jhum field at Bandarban and reached the highest (11.69) and the infestation remain static up to 2nd week of September. Furthermore, comparatively lower infestation during the year (2016) were observed at both experimental jhum fields of Rangamati and Khagrachari and reached a peak of 4.68 and 3.92 on the of 1st and end of the 3rd week of August, respectively. Among the three experimental fields, both years (2015 and 2016) grasshopper infestation at Bandarban was more than the other two hill districts.



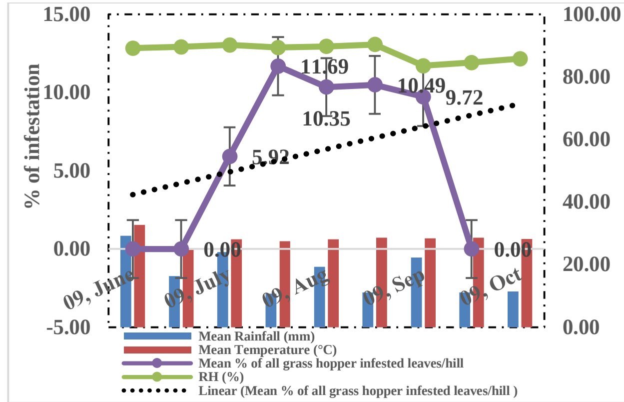
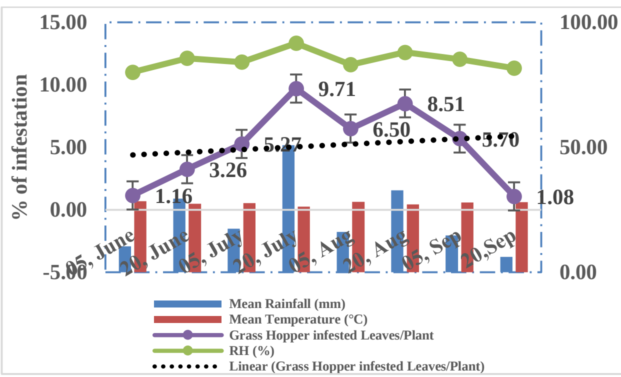


Figure 4.3.1.28 (a) Bandarban during 2015. **Figure 4.3.1.28 (d) Bandarban during 2016.**

Figure 4.3.1.28 (a & d) Seasonal grasshopper infested leaves plant^{-1} on rice in jhum field at Bandarban during 2015 and 2016.



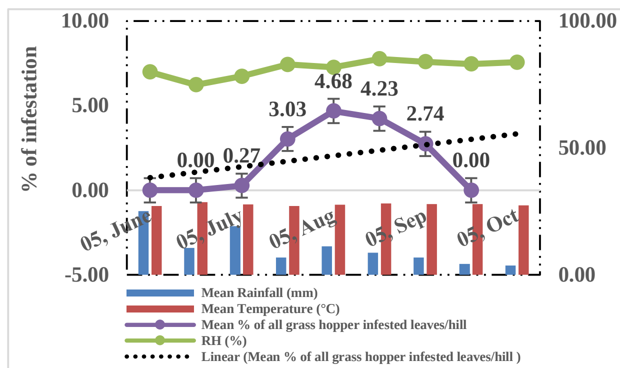
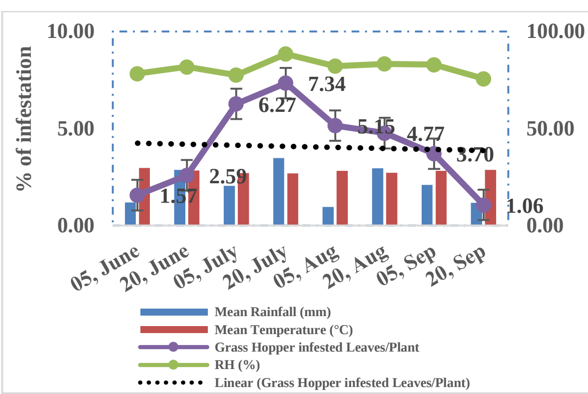


Figure x 4.3.1.28 (b) Rangamati during 2015. **Figure 4.3.1.28 (e) Rangamati during 2016.**

Figure 4.3.1.28 (b & e) Seasonal grasshopper infested leaves plant^{-1} on rice in jhum field at Rangamati during 2015 and 2016.



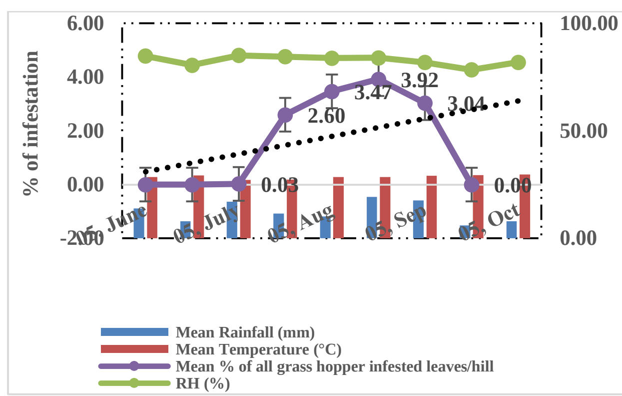


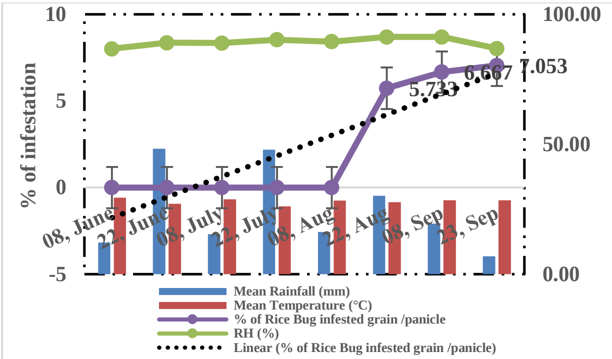
Figure 4.3.1.28 (c) at Khagrachari during 2015. **Figure 4.3.1.28 (f) at Khagrachari during 2016.**

Figure 4.3.1.28 (c & f) Seasonal grasshopper infested leaves plant^{-1} on rice in jhum field at Khagrachari during 2015 and 2016.

4.3.1.29 Dynamics of rice bug infestation on rice in jhum field

During the year 2015 and 2016, population levels of rice bug attacking rice grain panicle^{-1} at all the hill districts are shown in Figure 4.3.2.1.29 (a, b and c) and 4.3.2.1.29 (d, e and f). The jhum farmers' traditionally harvest their rice grain just cut the panicle with grains reasonably earlier than the plane land to save from falling grains and avoid environmental calamities. Figures 4.3.1.29 (a, b and c) revealed that the of rice bug infestation was started just after milking stage at Khagrachari with very low level during the 1st week of August and reached maximum of 9.35 at the end of 3rd week of September. Whereas at the end of the 3rd week of August visible infestation occur and continued up to the matured stage of the grain and reached a maximum of 7.05 and 6.56 during 4th and end of the 3rd week of September at Bandarban and Rangamati, respectively.

During the year 2016, preliminary insignificant infestation started on 1st and 2nd week of August at all experimental fields and kept its infestation steady and amplified throughout the panicle initiation stage. Infestation level reached a maximum of 5.56, 4.95 and 4.31 at the end of the 3rd week of September at Khagrachari, Bandarban and Rangamati, respectively. The overall grain infestation was higher and showing upper incursion revealed during 2015 at all the experimental fields than 2016. General inclinations of mean percent infestation of rice bug on grains panicle^{-1} occurred just after starting milking and continued up to stage to before ripened stage during both years and showing positive linear tendency at Bandarban, Rangamati and Khagrachari.



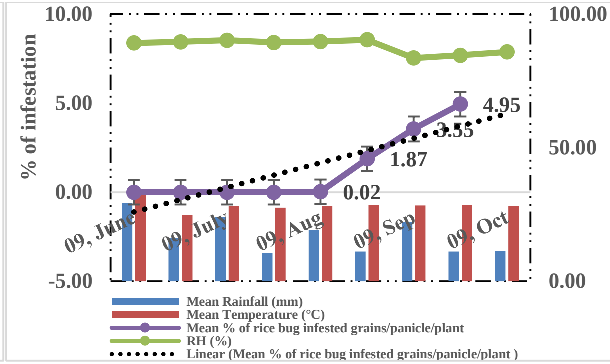
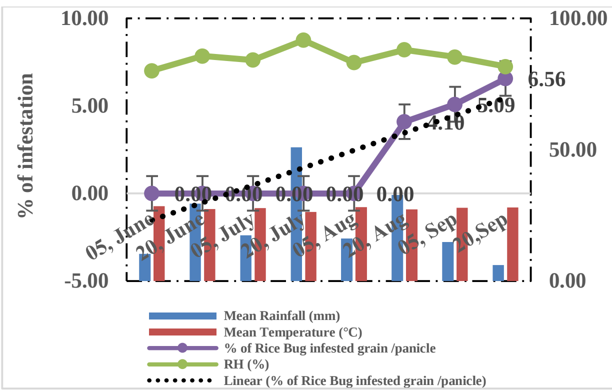


Figure 4.3.1.29 (a) Bandarban during 2015. **Figure 4.3.1.29 (d) Bandarban during 2016.**

Figure 4.3.1.29 (a & d) Seasonal rice bug infested grain panicle^{-1}hill^{-1} on rice in jhum field at Bandarban during 2015 and 2016.



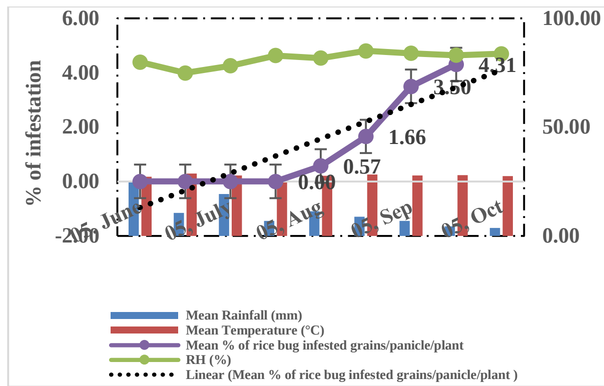
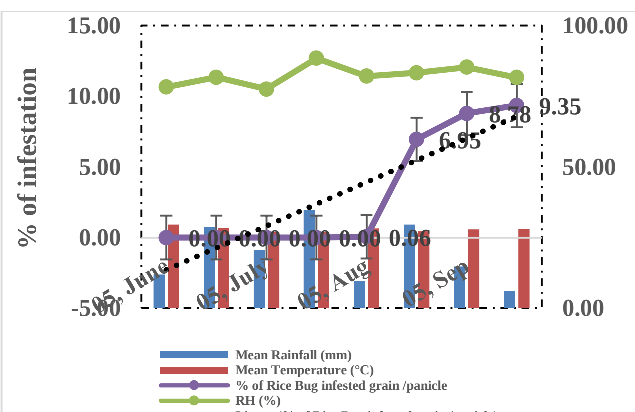


Figure 4.3.1.29 (b) Rangamati during 2015. **Figure 4.3.1.29 (e) Rangamati during 2016.**

Figure 4.3.1.29 (b & e) Seasonal rice bug infested grain panicle^{-1}hill^{-1} on rice in jhum field at Rangamati during 2015 and 2016.



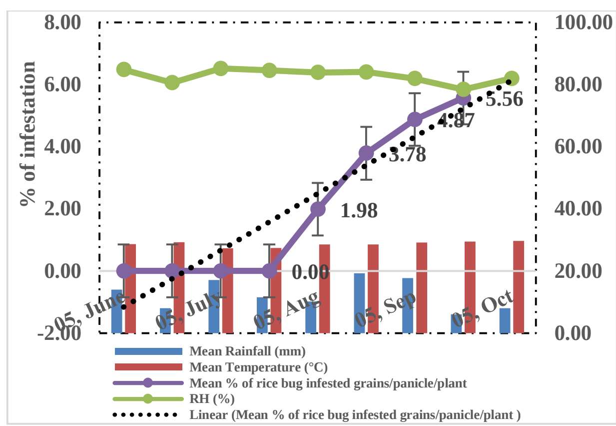


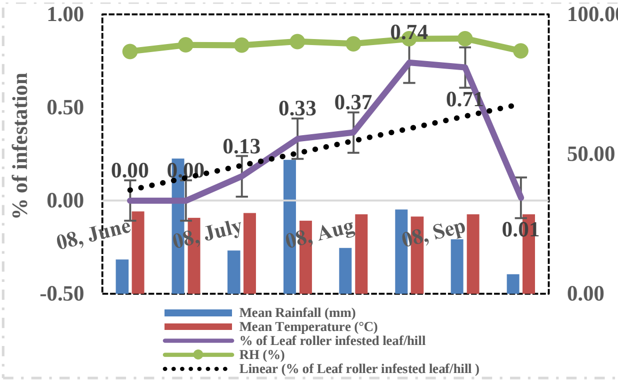
Figure 4.3.1.29 (c) at Khagrachari during 2015. **Figure 4.3.1.29 (f) at Khagrachari during 2016.**

Figure 4.3.1.29 (c & f) Seasonal rice bug infested grain panicle^{-1}hill^{-1} on rice in jhum field at Khagrachari during 2015 and 2016.

4.3.1.30 Dynamics of rice leaf folder infestation on rice in jhum field

During the year 2015 and 2016, population levels of rice leaf folder (RLF) attacking rice leaves at all hill districts are shown in Figure 4.3.1.30 (a, b and c) and 4.3.1.30 (d, e and f). Figures 4.3.1.30 (a, b and c) revealed that very low percent of RLF infestation started on 1st and 2nd week of July after of rice plant started tillering on the experimental jhum fields of Rangamati, Khagrachari and Bandarban. During the year 2015, afterwards, the initial RLF infestation gradually increased and reached a maximum of 0.64, 0.64 and 0.74 during the end of 3rd week of August when the rice plant grasped peak tillering stage at Bandarban, Rangamati and Khagrachari, respectively. After the peak infestation percentage slightly declined its damages on the leaves and thereafter the caterpillar disappear during the grain maturing stage.

Figures 4.3.1.30 (d, e and f) revealed that very scarce percent of RLF infestation started during the end of 3rd and 4th week of July at least 15 days later than the previous year in jhum fields at Rangamati, Khagrachari and Bandarban. During the year 2016, subsequently, initial percent infestation gradually increased reached a maximum of 2.66, 1.93 and 0.82 during the end of 2nd and 1st week of September, in addition to, the rice plant grabbed maximum tiller bearing stage at Bandarban, Rangamati and Khagrachari, individually. Similar disappearing of rice folder caterpillar was detected at later stage of rice plant as soon as leaves turned pale green to orange colour. The overall percentage of rice leaf folder infestation, higher infestation were revealed during 2016 than 2015. Among the three hill districts, comparatively the higher rate of infestation was found at Bandarban in both years.



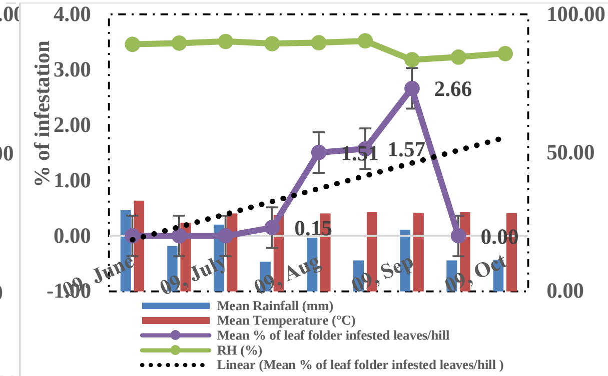
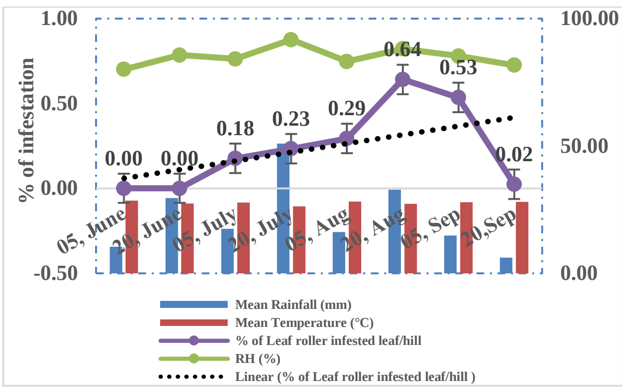


Figure 4.3.1.30 (a) Bandarban during 2015. **Figure 4.3.1.30 (d) Bandarban during 2016.**

Figure 4.3.1.30 (a & d) Seasonal rice leaf folder hill^{-1} on rice in jhum field at Bandarban during 2015 and 2016.



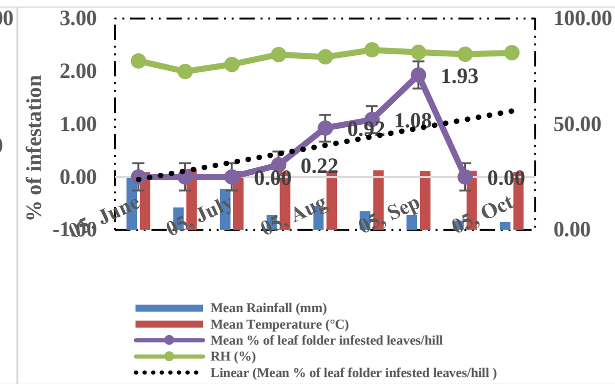
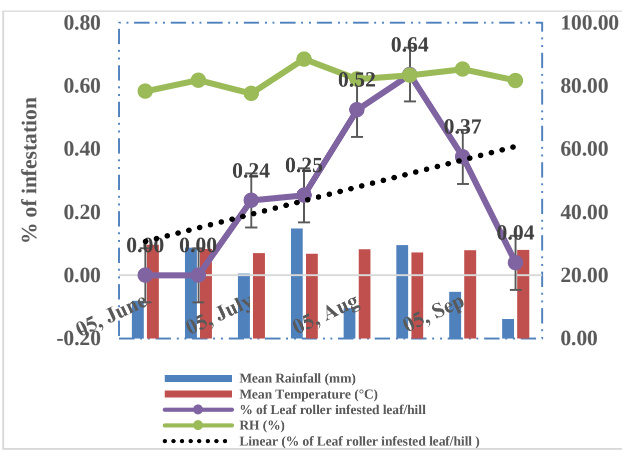


Figure 4.3.1.30 (b) Rangamati during 2015. **Figure 4.3.1.30 (e) Rangamati during 2016.**

Appendix 4.3.1.30 (b & e) Seasonal rice leaf folder hill^{-1} on rice in jhum field at Rangamati during 2015 and 2016.



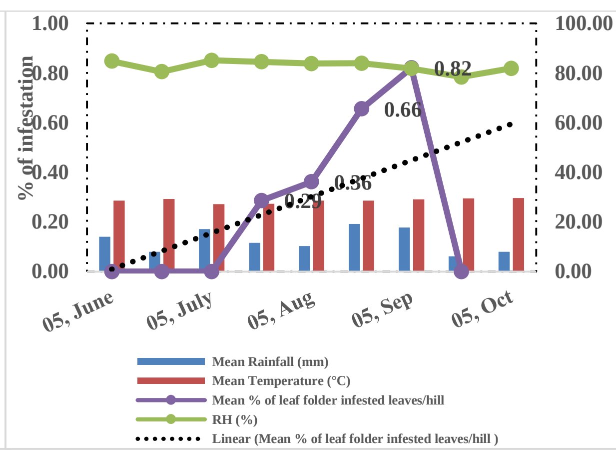


Figure 4.3.1.30 (c) at Khagrachari during 2015. **Figure 4.3.1.30 (f) at Khagrachari during 2016.**

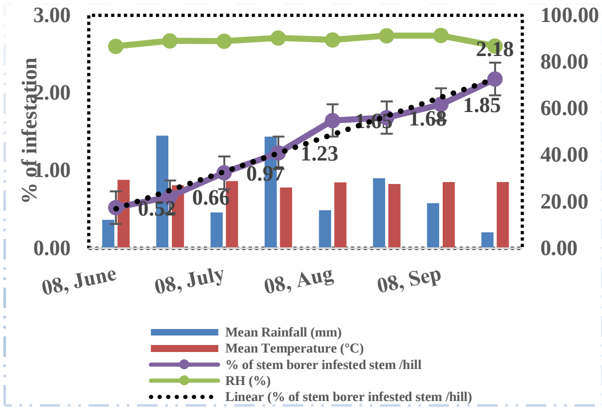
Figure 4.3.1.30 (c & f) Seasonal rice leaf folder hill^{-1} on rice in jhum field at Khagrachari during 2015 and 2016.

4.3.1.31 Dynamics of rice stem borer infestation on rice in jhum field

During the year 2015 and 2016, percent infestation of rice stem borer attacking rice stem at all the hill districts are shown in Figure 4.3.1.31 (a, b and c) and 4.3.1.31 (d, e and f).

Figures 4.3.1.31 (a, b and c) revealed that very low percent of rice stem borer infestation started during 1st and 2nd week of June after of rice plant arise from different experimental jhum fields at Rangamati, Khagrachari and Bandarban. Traditionally jhum farmers put more than two rice seeds in one hole which made by hook during sowing different seeds in late April to the early month of May. Therefore, without tillering one single pit have at least two individual rice plant. However, initial infestation by stem borer causes specific rice plant damage. After preliminary infestation with increasing their tiller number also infestation gradually increased and reached a peak of 2.09, 1.78 and 2.18 during the harvesting stage, i.e., at end of the month of September at Rangamati, Khagrachari and Bandarban, respectively.

Figures 4.3.1.31 (d, e and f) revealed that very low percent of rice stem borer infestation started during the end of 3rd and 4th week of July after the rice plant started producing tiller at all experimental jhum fields at Rangamati, Khagrachari and Bandarban. Preliminary infestation delayed due to heavy rainfall during late May to the early month of June 2016, consequently delayed the jhum seeds sowing, therefore, the rice plant arise comparatively later than the previous year. Then with the increasing number of tiller percent infestation of stem borer progressively increased and reached a maximum of 7.39, 7.05 and 6.63 before the harvesting of grain at Bandarban, Rangamati and Khagrachari one-to-one. Infestation percent of stem borer was considerably higher during the year 2016 than 2015. General inclinations of mean percent infestation of rice stem borer just after initiation of tillering stage to before harvesting in both the years were positive linear at Bandarban, Rangamati and Khagrachari.



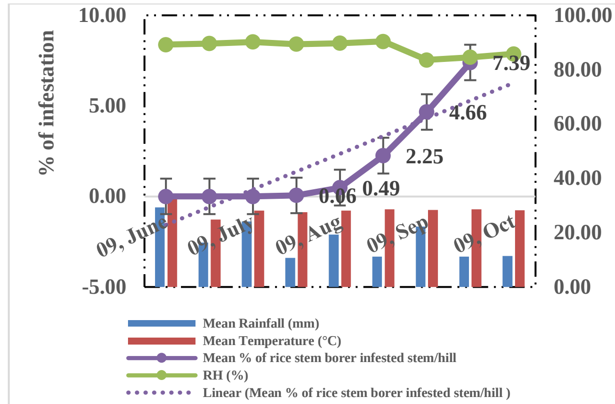
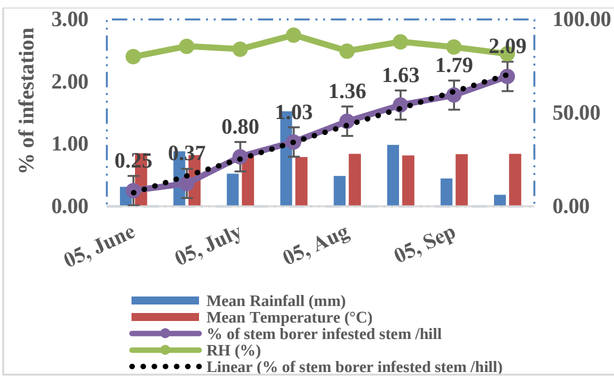


Figure 4.3.1.31 (a) Bandarban during 2015. **Figure 4.3.1.31 (d) Bandarban during 2016.**

Figure 4.3.1.31 (a & d) Seasonal rice stem borer infested stem hill^{-1} on rice in jhum field at Bandarban during 2015 and 2016.



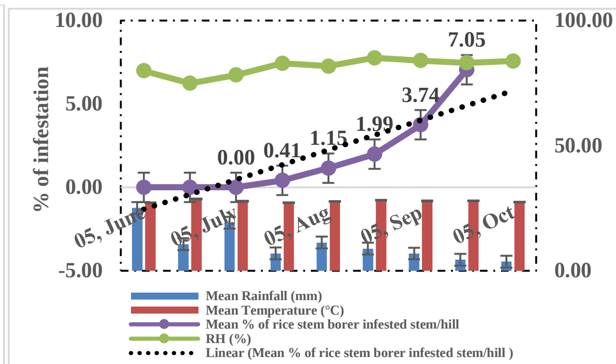
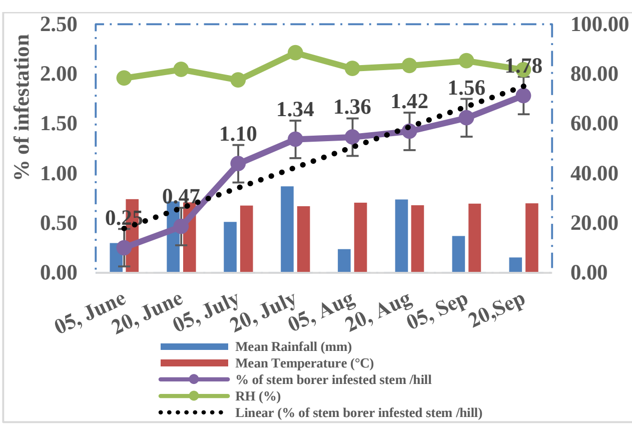


Figure 4.3.1.31 (b) Rangamati during 2015. **Figure 4.3.1.31 (e) Rangamati during 2016.**

Figure 4.3.1.31 (b & e) Seasonal rice stem borer infested stem hill^{-1} on rice in jhum field at Rangamati during 2015 and 2016.



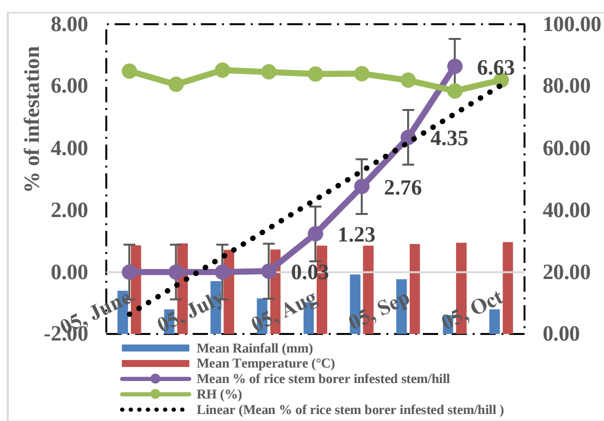


Figure 4.3.1.31 (c) at Khagrachari during 2015. **Figure 4.3.1.31 (f) at Khagrachari during 2016.**

Figure 4.3.1.31 (c and f) Seasonal rice stem borer infested stem hill^{-1} on rice in jhum field at Khagrachari during 2015 and 2016.

4.3.1.32 Dynamics of rice flea beetle infestation on rice in jhum field

During the year 2016, infestation percent of flea beetle attacking rice stem at all hill districts are shown in Figure 4.3.1.32 (a, b and c).

Figures 4.3.1.32 (a, b and c) revealed that the percent flea beetle infestation started during 1st and 2nd week of July at Bandarban and Rangamati, respectively. However, at Rangamati infestation was lower in compared to other two experimental fields and reach maximum (2.25) during 1st week of August, then infestation of flea beetle declined as well as the disappeared end of the month of August. After initial infestation both Bandarban and Rangamati percentage of flea beetle infestation gradually increased with an increasing number of tillering of the jhum rice and reached maximum of 24.77 and 30.93 during 1st and 4th week of August at Rangamati and Bandarban, correspondingly.

Then infestation intensity declined and flea beetle disappeared after mid-September. Experimental field of Bandarban was much affected than other two experimental fields of hill districts.

Tiny flea beetle scrapping the chlorophyll content from the tip of the rice leaves and consequently infested leaves look like hispa infested leaf. However, this insect was not found during the survey in 2014 and also the year 2015 at all my experimental fields of the above-mentioned districts.

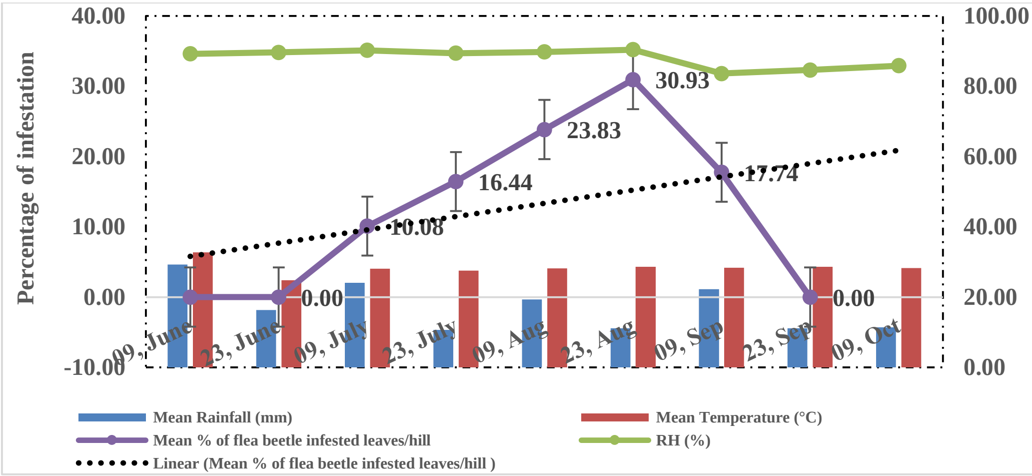


Figure 4.3.1.32 (a) Seasonal mean percentage of rice flea beetle infested leaves hill^{-1} on rice in jhum field at Bandarban during 2016.

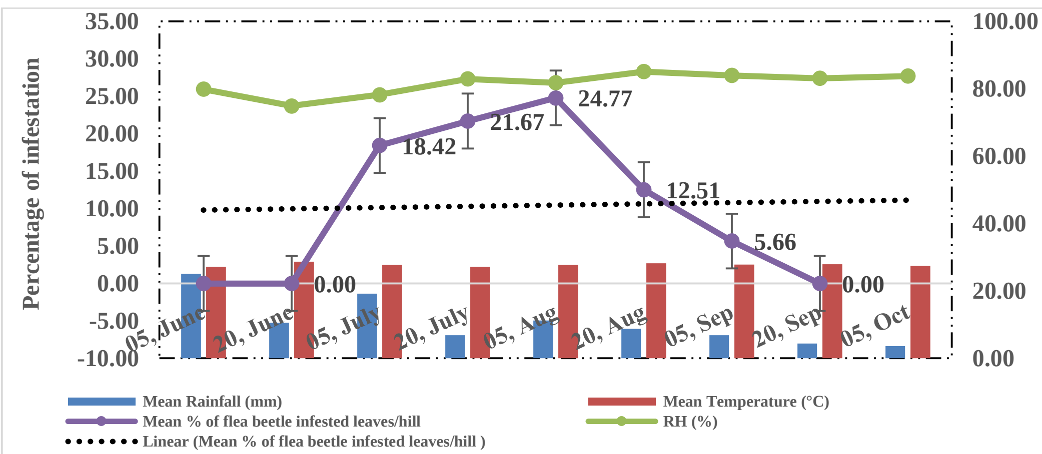


Figure 4.3.1.32 (b) Seasonal mean percentage of rice flea beetle infested leaves hill^{-1} on sesame in jhum field at Rangamati during 2016.

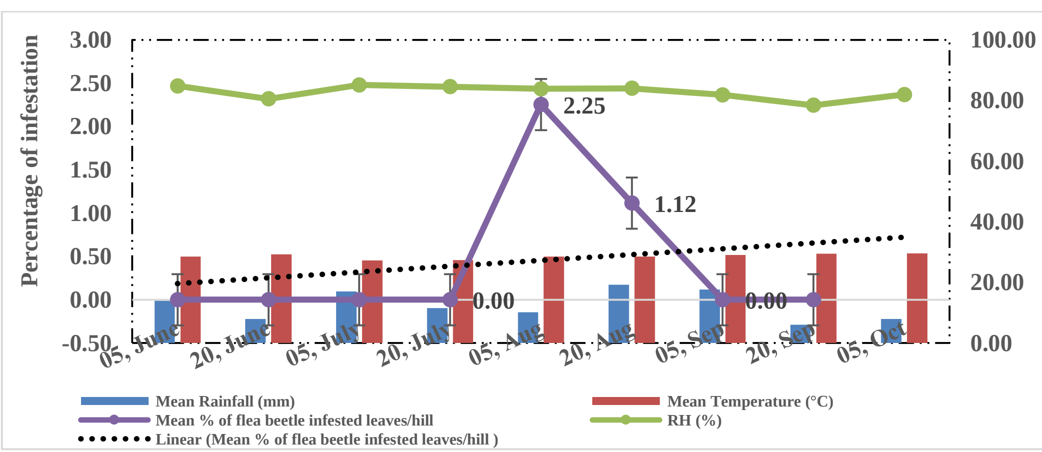


Figure 4.3.1.32 (c) Seasonal mean percentage of rice flea beetle infested leaves hill^{-1} on sesame in jhum field at Khagrachari during 2016.

4.3.1.33 Dynamics of termite infestation on rice in jhum field

During the year 2016, infestation percentage of termite attacking rice plant or root at all hill districts are shown in Figure 4.3.1.33 (a & b). Figures 4.3.1.33 (a & b) revealed that the percent termite infestation started during the end of the 3rd and 4th week of July at Bandarban and Rangamati, respectively. Only a small percentage of rice root as well as stem were infested by the termite and reached the maximum of 3.67 and 1.28 at Rangamati and Bandarban, respectively at that period indicated earlier. Jhum field prepared by slash and burning the selected hill slope early in the monsoon. Many weed and bushes were burned and their ashes mix with the expose soil, however, many inhabiting insects, mites and beneficial natural enemies and their eggs or immature stage were destroyed. The presence of termite mount might to some extent cause damage to the jhum crops. Termites prefer standing trees those are dry up during firing and burning at the time of jhum field preparation.

In the rice fields of jhum, termite infestation occur for short duration and nonappearance after the month of July whereas, termite infestation was not revealed at Khagrachari jhum experimental fields. Though the infestation was non-significant at both Rangamati and Bandarban nevertheless termite-infested rice plant 100% destroyed. For future selection, the hill slope for jhum cultivation should be carefully selected termite mount and if any must be eradicated otherwise, it may cause severe damage within a short time.

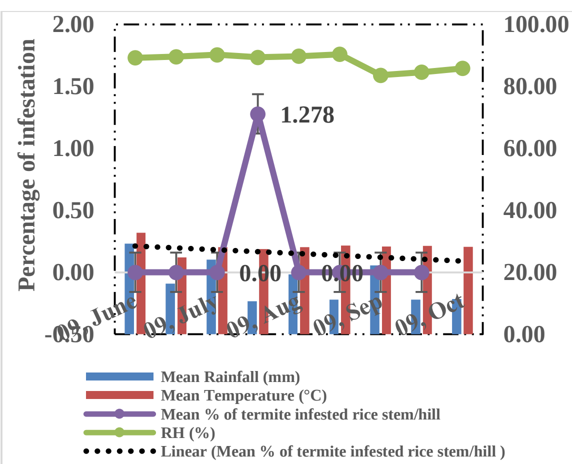


Figure 4.3.1.33 (a) Seasonal mean percentage of termite infested plant on rice in jhum field at Bandarban during 2016.

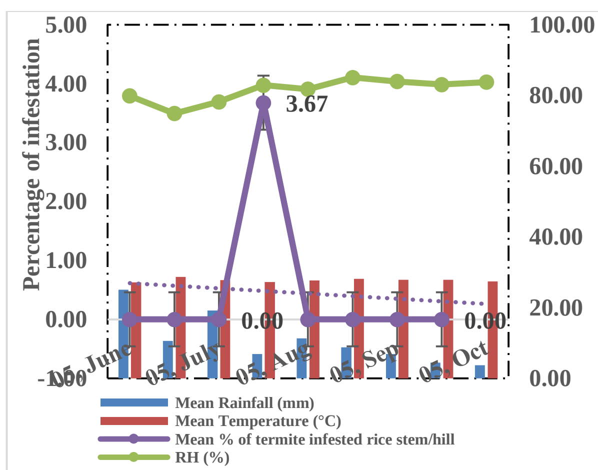


Figure 4.3.1.33 (b) Seasonal mean percentage of termite infested plant on rice in jhum field at Rangamati during 2016.

4.3.2 Population dynamics and extent of damage of major insect pests found in the rice-cotton intercropping system

The experiment was conducted in the farmer's field at hill districts of Bandarban, Rangamati and Khagrachari from 2015 to 2016. The main target of the experiment was to study the dynamics of insect pests in hill region of Bangladesh and to determine the extent of damage caused by different insect and mite pests of cotton-rice intercrop.

4.3.2.1 Dynamics of insect and mite pests of cotton in intercrop field.

The insect mite pests of cotton-rice intercrop and their dynamics of the population, as well as infestation, were studied and the results have been discussed and interpreted in this section below under the following sub-headings:

4.3.2.2 Dynamics of cotton aphid on intercrop cotton

During the year 2016, the percentage of aphid infestation on cotton leaves at Bandarban, Rangamati and Khagrachari are shown in Figure 4.3.2.1 (a, b and c). Figures revealed that aphid infestation started at the early stage of cotton leaves appear from the intercrop with the percent aphid infested leaf plant^{-1} were 17.52, 7.80 and 5.65 at Rangamati, Khagrachari and Bandarban, respectively during the end of 3rd week of July, which was a comparatively higher infestation of aphid leaf^{-1} then the previous year. During the previous year mean rainfall was higher and resulted lower infestation up to end of August. Although, the percent of aphid infested leaf plant^{-1} were soon increased and reached highest level of 48.28, 46.42 and 46.77 during the end of 3rd and 4th week of July at Khagrachari, Rangamati and Bandarban, respectively. Then percentage of infestation was more or less identical up to end of 3rd week of October at all intercrop experimental cotton fields. Suddenly mean rainfall increased during the end of the year 2016, as aresult percent of infestation decreased and disappeared at the later stage of the crop. The trends of percent of aphid leaf^{-1} during 2016 were higher infestation at all experimental intercrop field of Bandarban, Rangamati and Khagrachari.

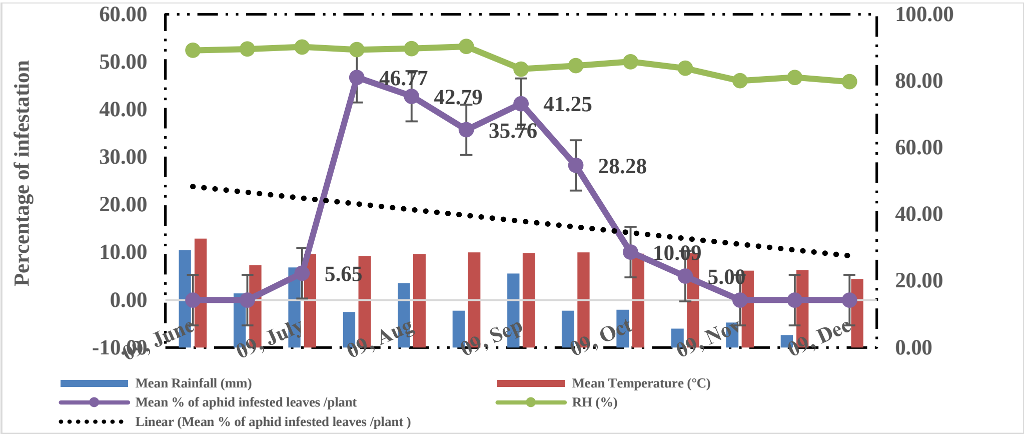


Figure 4.3.2.1 (a) Seasonal aphid infested leaves plant^{-1} on cotton in intercrop field at Bandarban during 2016.

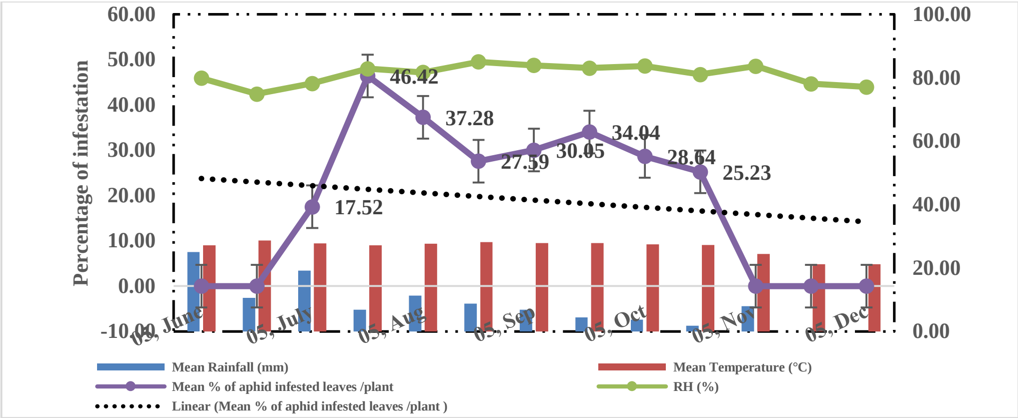


Figure 4.3.2.1 (b) Seasonal aphid infested leaves plant^{-1} on cotton in intercrop field at Rangamati during 2016.

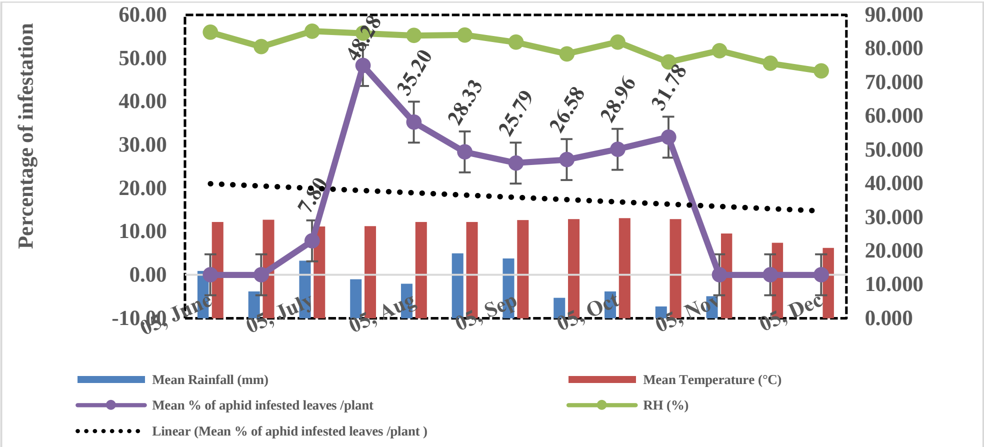


Figure 4.3.2.1 (c) Seasonal aphid infested leaves plant^{-1} on cotton in intercrop field at Khagrachari during 2016.

4.3.2.3 Dynamics of cotton jassid on intercrop cotton

During the year 2016, population levels of jassid attacking cotton leaves at Bandarban, Rangamati and Khagrachari are shown in Figure 4.3.2.2 (a, b and c). Figures revealed that jassid infestation started during 1st and 2nd week of July with comparatively higher infestation was found at Khagrachari and Bandarban and Rangamati than the previous year. Then the percentage of infestation showed similar tendency at all the three hill experimental fields but mean rainfall comparatively higher than the previous year at Khagrachari resulted lower infestation. With decreasing mean rainfall and temperature, infestation percent regularly increased and touched the highest peak of 14.53 and 13.34 during the end of the season i.e., end of December. However, at Khagrachari infestation reached its peak of 10.78 during the end of 3rd week of October but rest of the season jassid maintain their infestation percentage alike. Among the sucking insects pest, jassid infestation comparatively lower than aphid during both year at all experimental fields of hill districts.

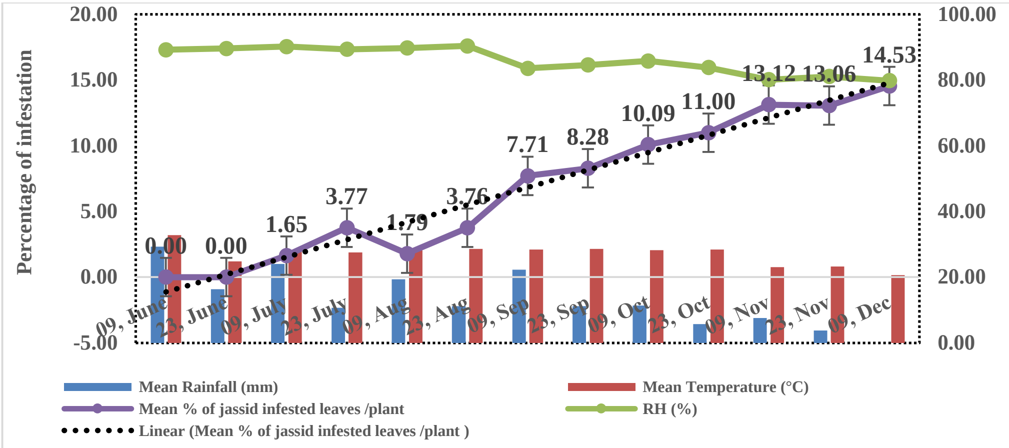


Figure 4.3.2.2 (a) Seasonal jassid infested leaves/plant on cotton in intercrop field at Bandarban during 2016.

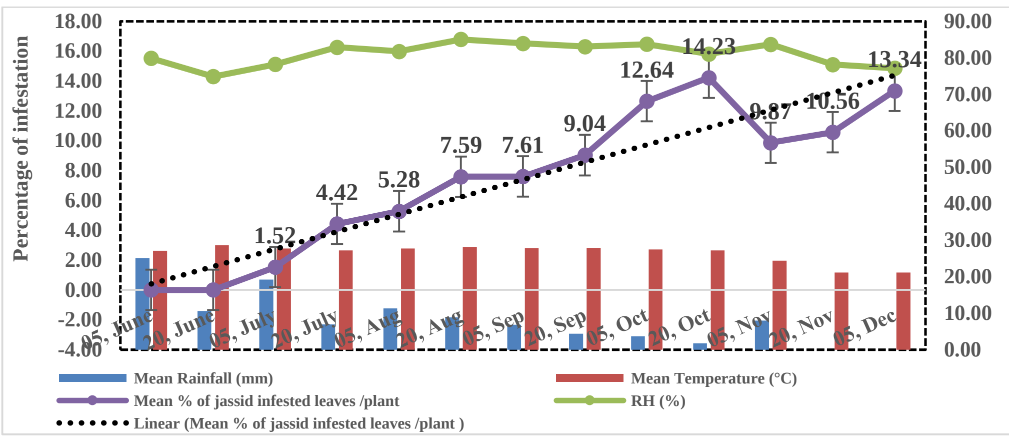


Figure 4.3.2.2 (b) Seasonal jassid infested leaves/plant on cotton in intercrop field at Rangamati during 2016.

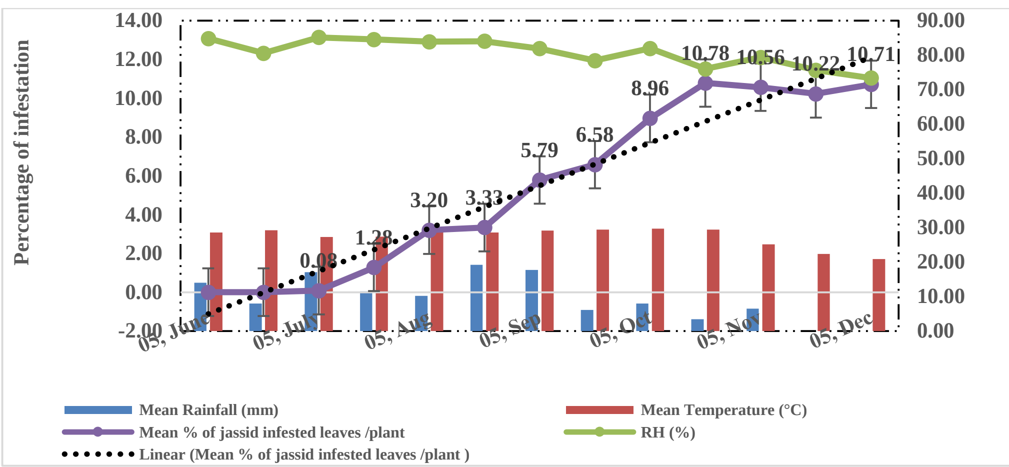


Figure 4.3.2.2 (c) Seasonal jassid infested leaves/plant on cotton in intercrop field at Khagrachari during 2016.

4.3.2.4 Dynamics of cotton whitefly on intercrop cotton

During the year 2015 and 2016, population levels of whitefly attacking cotton leaves at Bandarban, Rangamati and Khagrachari are shown in Figure 4.3.2.3 (a, b and c) and 4.3.2.3 (d, e and f). Figures revealed that whitefly infestation started in the year of 2015 during 1st and 2nd week of September at Rangamati and Bandarban, respectively whereas, the infestation starts at the end of month September at Khagrachari with decreasing mean rainfall. Whereas the percent infestation in the year 2016 were observed fifteen days earlier than the previous year (2015).

Figure 4.3.2.3 (a, b and c) revealed that with decreasing the mean rainfall and temperature percent infestation gradually increased and reached a maximum of 19.26, 16.26 and 14.26 during the end of the December when no rainfall was recorded at Bandarban, Khagrachari and Rangamati. After 1st the week of November, the percent infestation increased rapidly at all the experimental fields during the year 2015, however during October and November 2016 mean rainfall was comparatively higher than a previous year (2015) thus the whitefly disappear after 2nd week of November.

During the year 2016, [Figures (d, e and f)] revealed that whitefly infestation throughout the year was much lower than the previous year and reached highest of 5.30, 4.03 and 3.37 during the end of 3rd and 4th week of October at Rangamati, Khagrachari and Bandarban respectively. The overall whitefly percent infestation of leaves plant^{-1} was much lower than the previous year (2015).

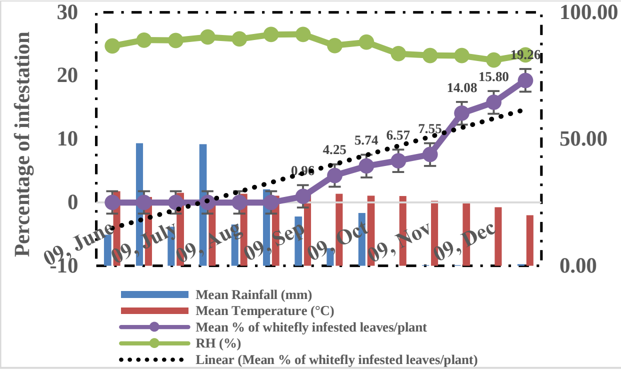


Figure 4.3.2.3 (a) Bandarban during 2015.

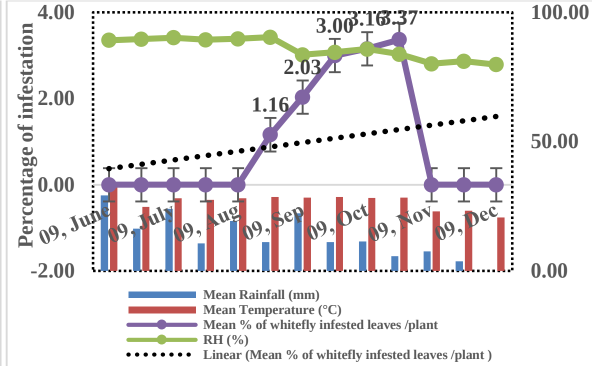


Figure 4.3.2.3 (d) Bandarban during 2016.

Figure 4.3.2.3 (a & d) Seasonal whitefly infested leaves plant^{-1} on cotton in intercrop field at Bandarban during 2015 and 2016.

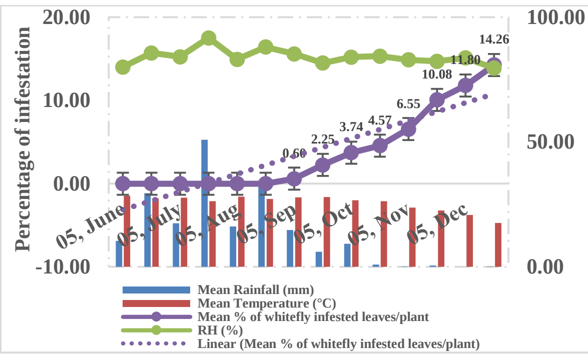


Figure 4.3.2.3 (b) Rangamati during 2015.

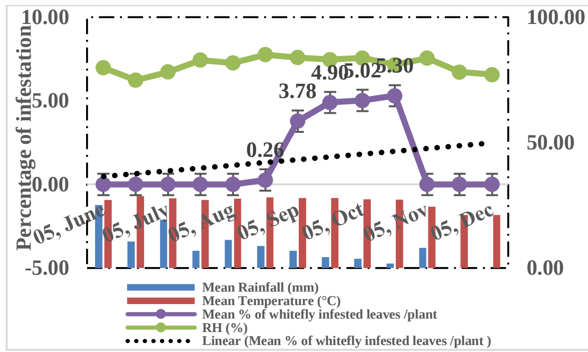


Figure 4.3.2.3 (e) Rangamati during 2016.

Figure 4.3.2.3 (b & e) Seasonal whitefly infested leaves plant^{-1} on cotton in intercrop field at Rangamati during 2015 and 2016.

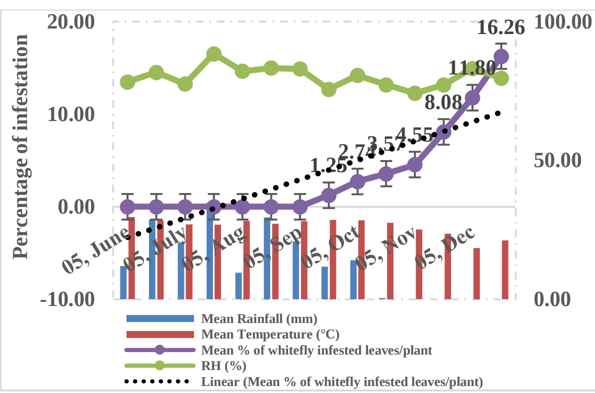


Figure 4.3.2.3 (c) at Khagrachari during 2015.

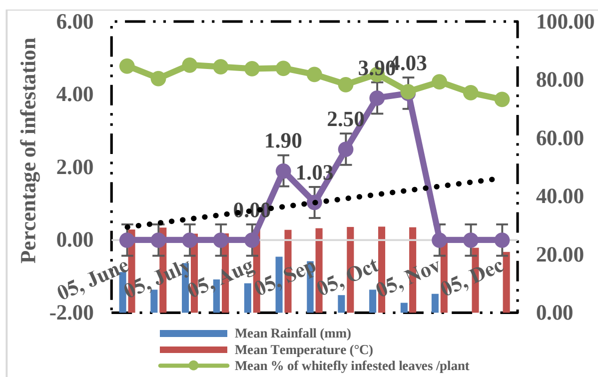


Figure 4.3.2.3 (f) at Khagrachari during 2016.

Figure 4.3.2.3 (c & f) Seasonal whitefly infested leaves plant^{-1} on cotton in intercrop field at Khagrachari during 2015 and 2016.

4.3.2.5 Population dynamics of cotton bollworm on intercrop cotton

During the year 2016, comparatively higher percentage of infestation was observed than the previous year and reached the maximum (3.58) during 1st week of September at Khagrachari, than declined sharply and prevailed their infestation up to end of November. At Rangamati and Bandarban after initial infestation prevailed and reached the peak of 3.76 and 1.04 during the end of the 3rd week of October and the 2nd week of November, correspondingly. Furthermore, the percent infestation declined after the end of November at all the experimental fields of three hill districts when temperature and rainfall decreased.

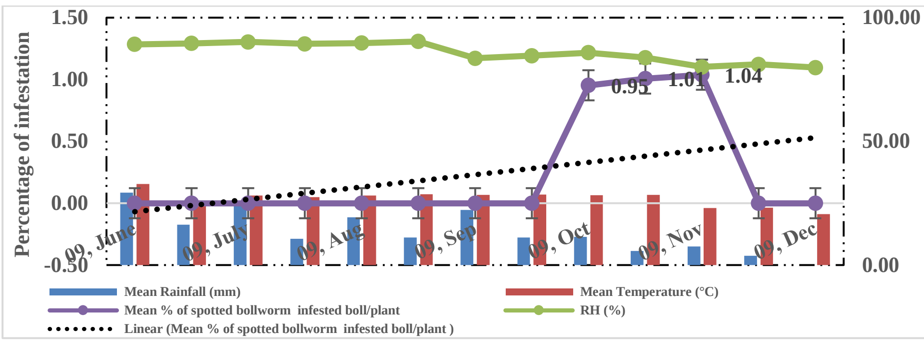


Figure 4.3.2.4 (a) Seasonal cotton bollworm infested boll plant^{-1} on cotton in intercrop field at Bandarban during 2016.

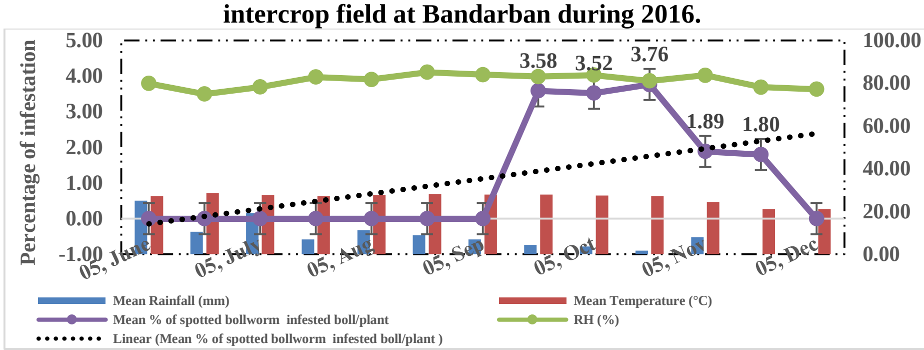


Figure 4.3.2.4 (b) Seasonal cotton bollworm infested boll plant^{-1} on cotton in intercrop field at Rangamati during 2016.

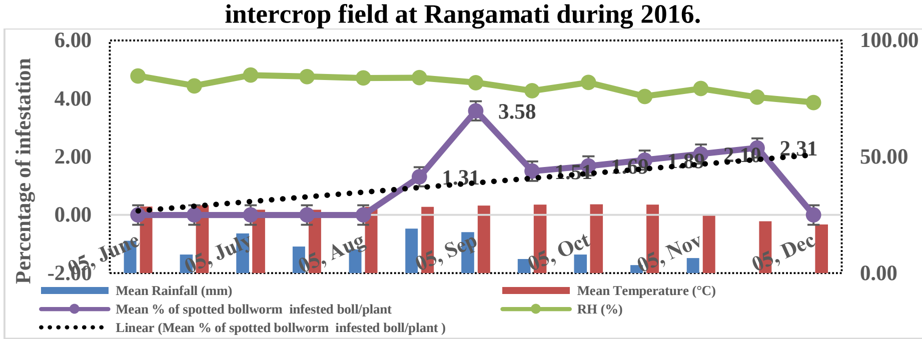


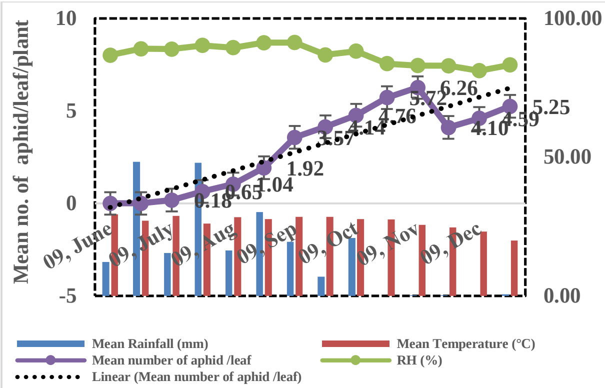
Figure 4.3.2.4 (c) Seasonal cotton bollworm infested boll plant^{-1} on cotton in intercrop field at Khagrachari during 2016.

4.3.2.6 Population dynamics of aphid on intercrop cotton

During the year 2015, population levels of aphid attacking cotton at Bandarban, Rangamati and Khagrachari are shown in Figure 4.3.2.5 (a, b and c). Figures revealed that aphid infestation started at the early stage of cotton leaves appear from the cotton plant in rice-cotton intercrop with the number of aphid leaf^{-1} were (0.18, 0.12 and 0.19) at Bandarban, Rangamati and Khagrachari, respectively during early week of July. With increasing of rainfall and temperature, the population of aphid leaf^{-1} increased very slowly up to the end of August at all experimental region of hill districts. With decreasing of rainfall the population of aphid leaf^{-1} increased gradually and reached pick of 7.26 and 6.26 during the end of 3rd and beginning of 4th week of November at Khagrachari and Bandarban, respectively whereas, at Rangamati highest number of aphid leaf^{-1} (5.67) was observed at the end of the 3rd week of December.

During the year 2016, population levels of aphid attacking cotton leaves at Bandarban, Rangamati and Khagrachari are shown in Figure 4.3.2.5 (d, e and f). Figures revealed that aphid infestation was comparatively higher than the previous year and started at the early stage of cotton leaves appear on the cotton plant from the rice-cotton intercrop field with the number of aphid leaf^{-1} were 9.16, 8.45 and 7.52 at Bandarban, Khagrachari and Rangamati, respectively thru the end of 3rd week of July. Higher mean rainfall during 2nd half of July 2016 affected the population at an early stage of the cotton plant.

Then the number of aphid leaf^{-1} were steadily lesser throughout the ball setting and maturing stage at Bandarban and Khagrachari. With decreasing mean rainfall after August, population increased upto 2nd highest (6.02) at the 1st week of October than declined sharply at later stage of the crop at Rangamati. Comparatively higher number of aphid leaf^{-1} were observed during the year 2016 at the early stage of intercrop cotton than the previous year at all experimental fields of hill districts.



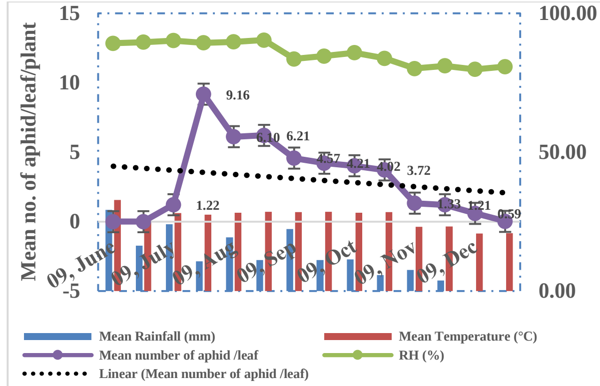
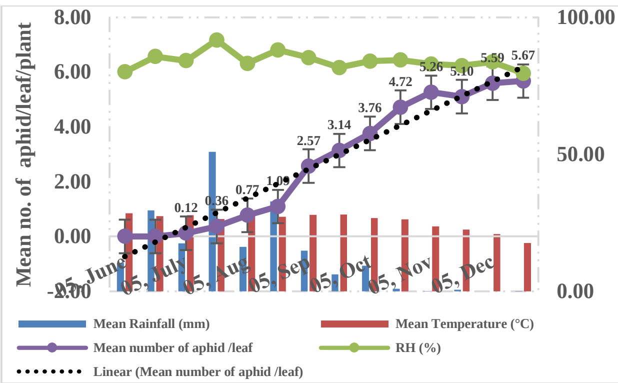


Figure 4.3.2.5 (a) Bandarban during 2015.

Figure 4.3.2.5 (d) Bandarban during 2016.

Figure 4.3.2.5 (a & d) Seasonal cotton aphid number leaf^{-1} plant^{-1} on cotton in intercrop field at Bandarban during 2015 and 2016.



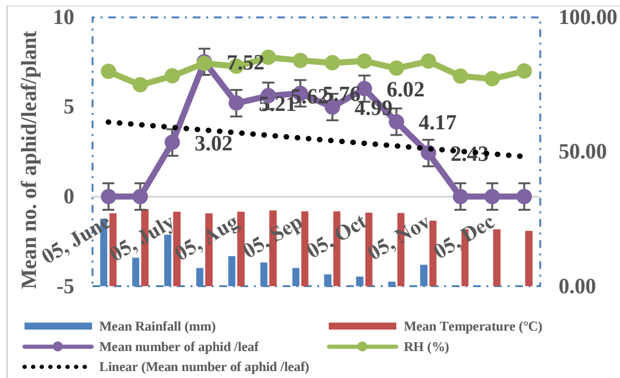
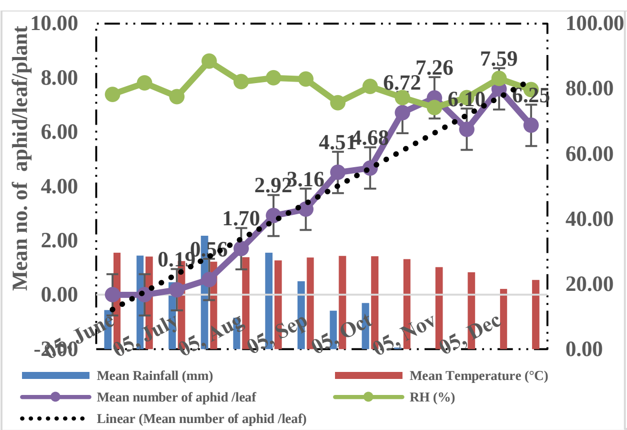


Figure 4.3.2.5 (b) Rangamati during 2015.

Figure 4.3.2.5 (e) Rangamati during 2016.

Figure 4.3.2.5 (b & e) Seasonal aphid number leaf^{-1} plant^{-1} on cotton in intercrop field at Rangamati during 2015 and 2016.



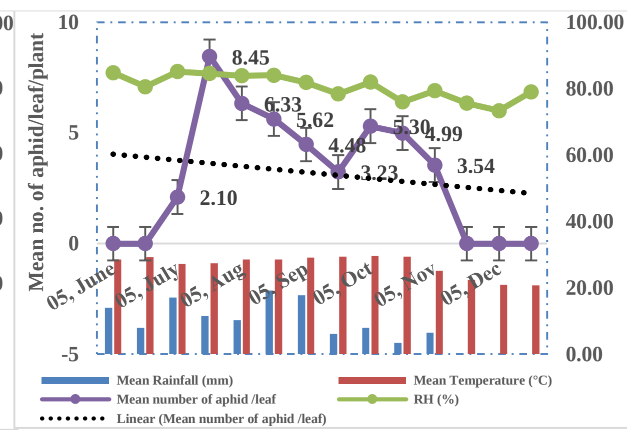


Figure 4.3.2.5 (c) at Khagrachari during 2015.

Figure 4.3.2.5 (f) at Khagrachari during 2016.

Figure 4.3.2.5 (c & f) Seasonal aphid number leaf^{-1} plant^{-1} on cotton in intercrop field at Khagrachari during 2015 and 2016.

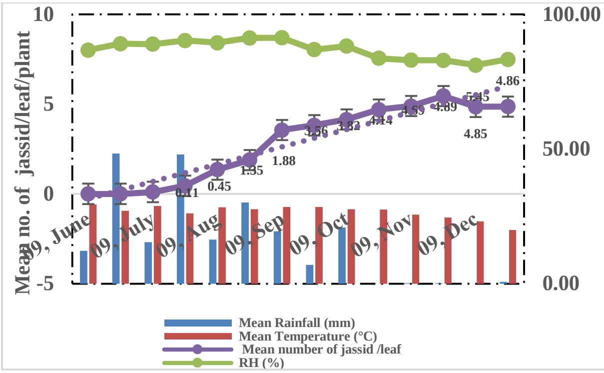
4.3.2.7 Population dynamics of jassid on intercrop cotton

During the year 2015, population levels of jassid attacking cotton leaves at all hill districts are shown in Figure 4.3.2.6 (a, b and c). Figures revealed that jassid infestation started at the early stage of cotton leaves arise from the cotton plant in intercrop field with the number of jassid leaf^{-1} which was insignificant (0.11, 0.15 and 0.14) at Bandarban, Rangamati and Khagrachari respectively during early week of July. Then the number of jassid leaf^{-1} were leisurely increased at the end of August at all the experimental fields of hill districts.

With decreasing the mean rainfall, population steadily increased and reached the highest of 6.45, and 5.45 during the end of the 3rd and 4th week of November at Khagrachari and Bandarban, respectively. Whereas, a similar trend of population leaf^{-1} was observed and reached a peak of 5.85 during the 1st week of December at Rangamati.

During the year 2016, population levels of jassid attacking cotton leaves at Bandarban, Rangamati and Khagrachari are shown in Figure 4.3.2.6 (d, e and f). Figures revealed that jassid infestation started at the early stage of the cotton plant appear in rice-cotton intercrop with several jassid leaf^{-1} which was 0.11, 0.09 and 0.05 at Bandarban, Rangamati and Khagrachari, respectively during early week of July, which was equal or less number of jassid leaf^{-1} then the previous year (2015). After the initial infestation population number gradually increase up to the early month of October at both Bandarban and Rangamati then to some extent declined the population with increasing rainfall.

With decreasing mean rainfall and temperature population again increased and reached a maximum of 5.3 and 6.34 during the end of the season i.e., 3rd and starting on the 4th week of December. Moreover, temperature decrease at the later season with little mean rainfall at the experimental field of Khagrachari, population increased slowly throughout the year and reached a peak of 5.07. The trend showing the mean number of jassid leaf^{-1} during 2015 and 2016 with seasonal incidence throughout the cotton crop were clearly shown positive linear at all experimental intercrop field of Bandarban, Rangamati and Khagrachari.



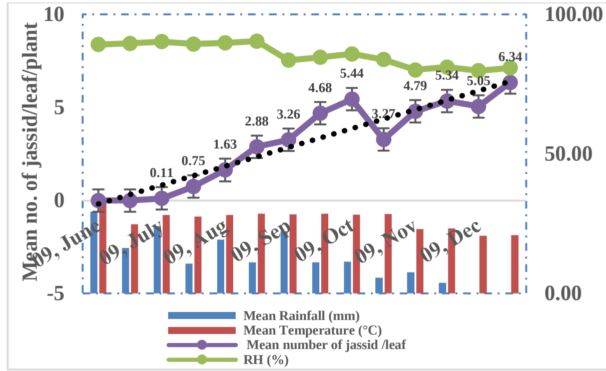
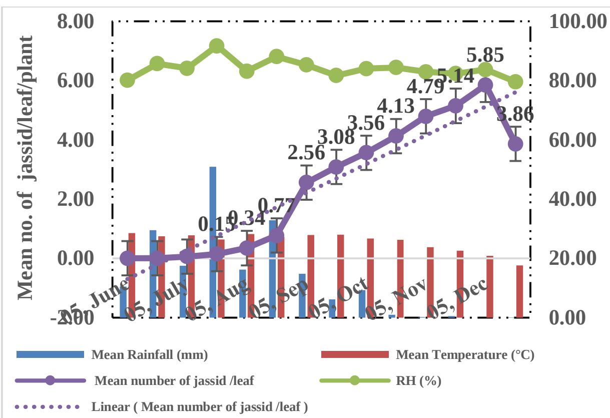


Figure 4.3.2.6 (a) Bandarban during 2015. **Figure 4.3.2.6 (d) Bandarban during 2016.**

Figure 4.3.2.6 (a & d) Seasonal cotton jassid number leaf^{-1} plant^{-1} on cotton in intercrop field at Bandarban during 2015 and 2016.



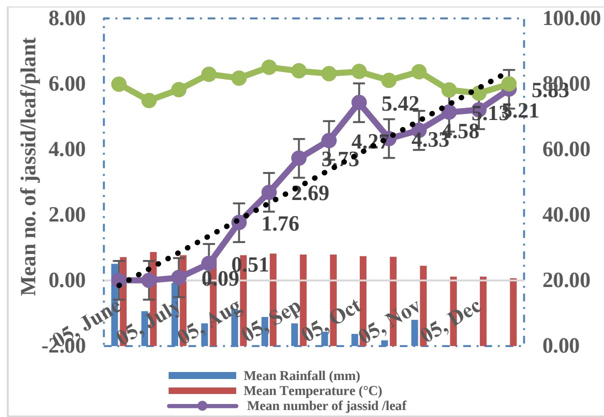
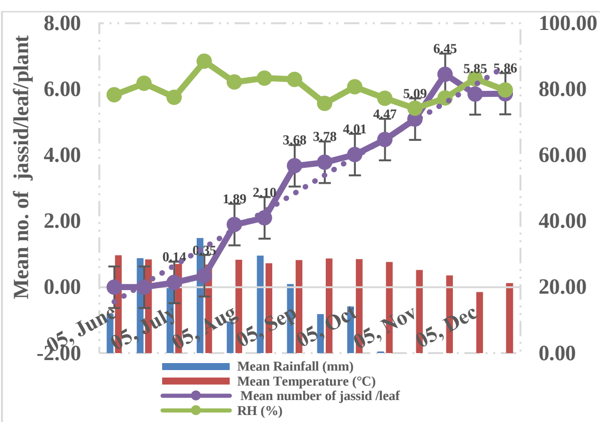


Figure 4.3.2.6 (b) Rangamati during 2015. **Figure 4.3.2.6 (e) Rangamati during 2016.**

Figure 4.3.2.6 (b & e) Seasonal jassid number leaf^{-1} plant^{-1} on cotton in intercrop field at Rangamati during 2015 and 2016.



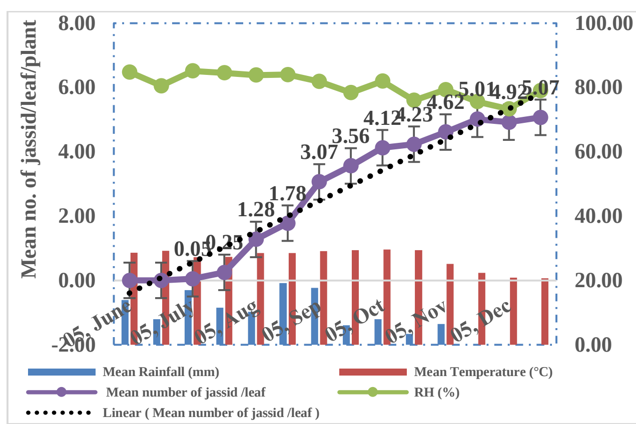


Figure 4.3.2.6 (c) at Khagrachari during 2015. **Figure 4.3.2.6 (f) at Khagrachari during 2016.**

Figure 4.3.2.6 (c & f) Seasonal jassid number leaf^{-1} plant^{-1} on cotton in intercrop field at Khagrachari during 2015 and 2016.

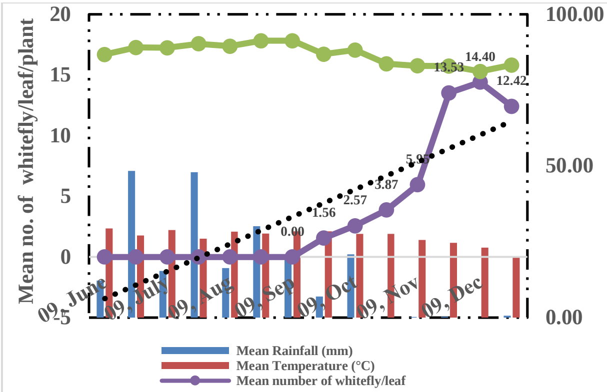
4.3.2.8 Population dynamics of whitefly on intercrop cotton

During the year 2015, population levels of whitefly attacking cotton leaves at all hill districts are shown in Figure 4.3.2.7 (a, b and c). Figures revealed that jassid infestation started at the early stage of cotton leaves arise from the cotton plants in intercrop field with a number of whitefly leaf^{-1} were insignificant during the end of 3rd week of August at Bandarban, Rangamati and Khagrachari. Then the number of whitefly leaf^{-1} were slowly increased at the end of October at all the experimental fields of hill districts.

With decreasing mean rainfall and temperature after 3rd week of October whitefly infested leaves plant^{-1} steadily advanced and touched the maximum of 14.44 for the period of the 2nd week of December at Bandarban whereas, a similar trend of population leaf^{-1} plant^{-1} were observed and reached the maximum of 13.54 and 9.42 during the end of December at Rangamati and Khagrachari, respectively.

During the year 2016, infestation levels of whitefly attacking cotton at all hill districts are shown in Figure 4.3.2.7 (d, e and f). Figures revealed that mean number of whitefly infested leaf plant^{-1} were started 75 days later after emerging cotton plant in intercrop field with an insignificant initial infestation at Rangamati, Khagrachari and Bandarban during the end of 3rd and 4th week of August. After initial infestation, its population gradually increased and reached the maximum of 11.19, 8.76 and 9.04 during the end of 3rd and 4th week of October at Rangamati, Khagrachari and Bandarban, one-to-one.

The overall trend of the mean number of whitefly leaf^{-1} during 2015 and 2016 with seasonal incidence all over the intercrop cotton was indeed positive linear. Betwen the two years suddenly the mean rainfall during the year 2016 were higher consequently whitefly population was much lower than the previous year at all experimental intercrop fields of Bandarban, Rangamati and Khagrachari.



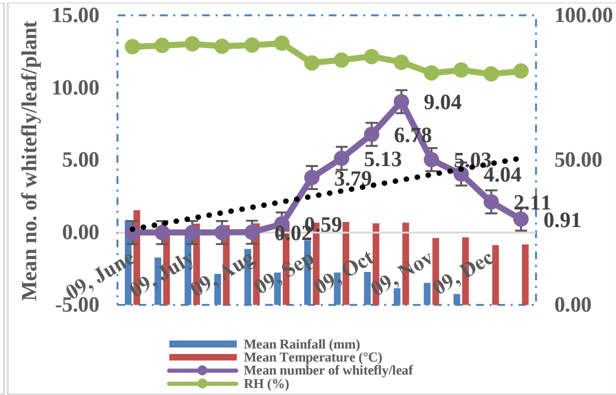
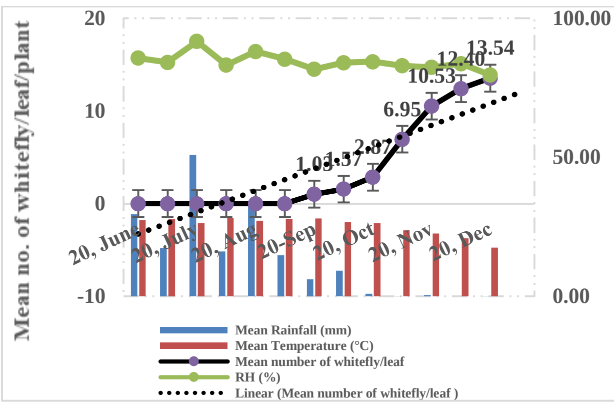


Figure 4.3.2.7 (a) Bandarban during 2015.

Figure 4.3.2.7 (d) Bandarban during 2016.

Figure 4.3.2.7 (a & d) Seasonal cotton whitefly number leaf^{-1} plant^{-1} on cotton in intercrop field at Bandarban during 2015 and 2016.



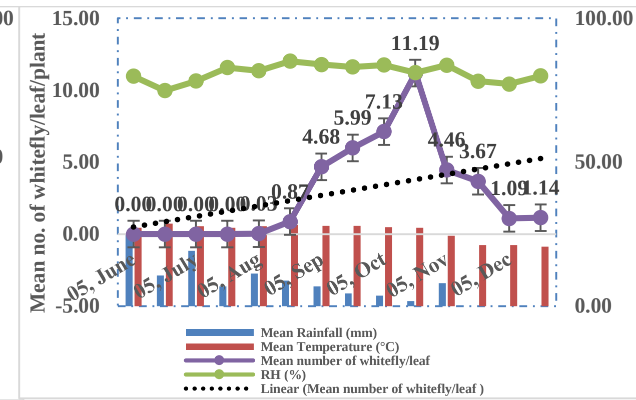
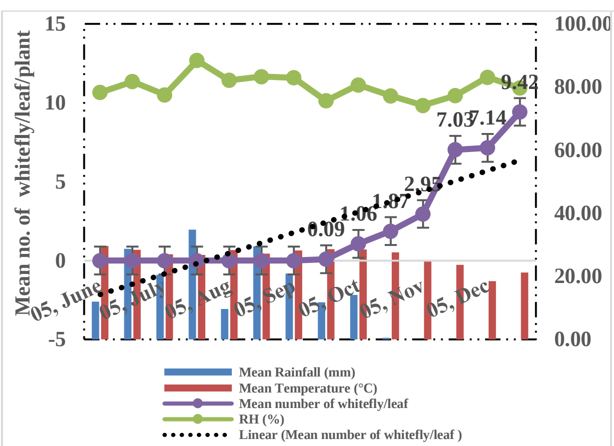


Figure 4.3.2.7 (b) Rangamati during 2015.

Figure 4.3.2.7 (e) Rangamati during 2016.

Figure 4.3.2.7 (b & e) Seasonal whitefly number leaf^{-1} plant^{-1} on cotton in intercrop field at Rangamati during 2015 and 2016.



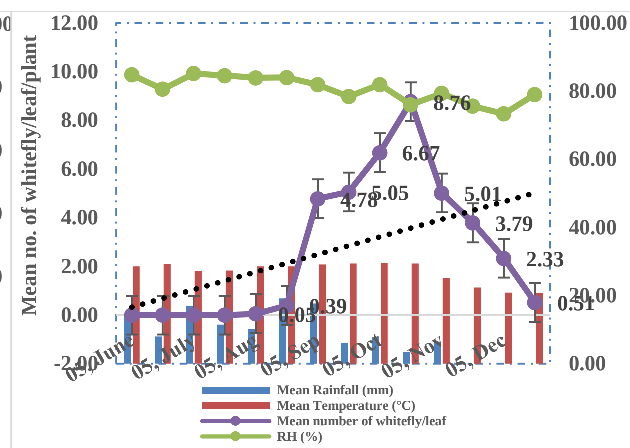


Figure 4.3.2.7 (c) at Khagrachari during 2015.

Figure 4.3.2.7 (f) at Khagrachari during 2016.

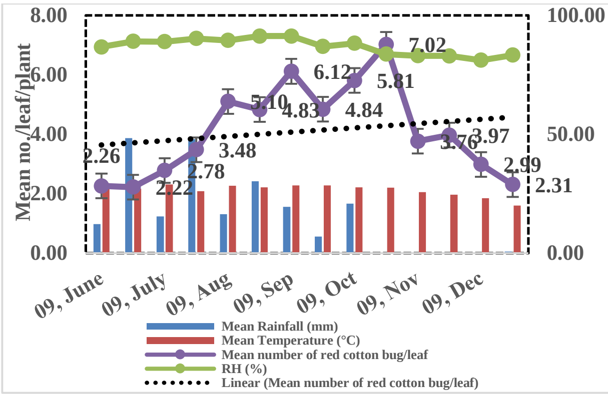
Figure 4.3.2.7 (c & f) Seasonal whitefly number leaf^{-1} plant^{-1} on cotton in intercrop field at Khagrachari during 2015 and 2016.

4.3.2.9 Population dynamics of red cotton bug on intercrop cotton

During the year 2015 and 2016, population levels of red cotton bug attacking cotton in intercrop at all hill districts are shown in Figure 4.3.2.8 (a, b and c) and 4.3.2.8 (d, e and f). Figures revealed that red cotton bug infestation started at the very early stage of cotton leaves arise from the cotton plant in intercrop with a number of red cotton bug leaf^{-1} plant^{-1} were few at Bandarban, Rangamati and Khagrachari, respectively during of 1st and 2nd week of June.

The overall trend of mean numbers of red cotton bug leaf^{-1} plant^{-1} during both 2015 and 2016 with seasonal incidence all over the intercrop cotton was positively linear. After initial infestation the number of red cotton bug gradually increased and reached the maximum of 6.02, 6.03 and 7.02 during the end of the 3rd and 4th week of October 2015 at Khagrachari, Rangamati and Bandarban, respectively. Then the population declined but continue their presence at the later stage of the cotton crop.

During the year 2016, a similar tendency of red cotton bug population was observed throughout the season. But the number of red cotton bug leaf^{-1} plant^{-1} has reached a peak of 6.23 and 7.13 during the end of 3rd and 4th week of August. Nevertheless, at Khagrachari touched the maximum of 5.90 at 1st week of September. Then population declined with decreasing mean rainfall and temperature at all experimental fields of hill districts. During both year, number of red cotton bug leaf^{-1} plant^{-1} was a little bit higher in 2016 than 2015 nonetheless population number and their fluctuation was similar inclination at intercrop cotton.



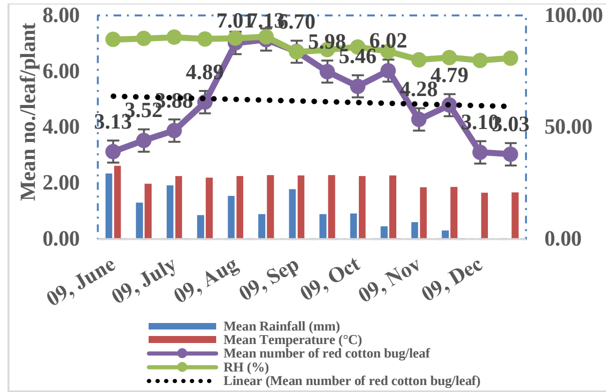
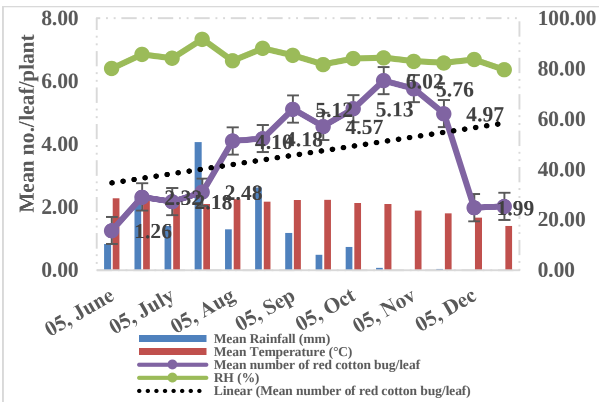


Figure 4.3.2.8 (a) Bandarban during 2015. **Figure 4.3.2.8 (d) Bandarban during 2016.**

Figure 4.3.2.8 (a & d) Seasonal red cotton bug number leaf^{-1} plant^{-1} on cotton in intercrop field at Bandarban during 2015 and 2016.



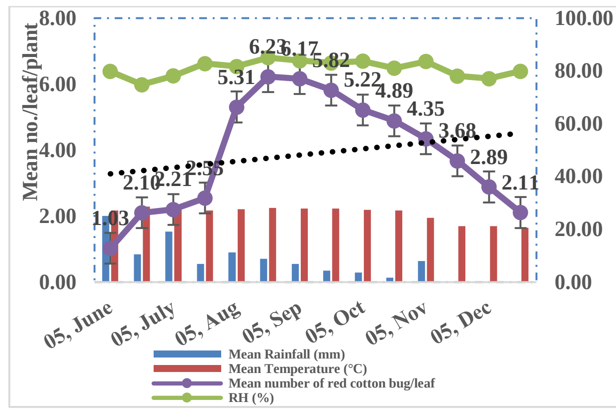
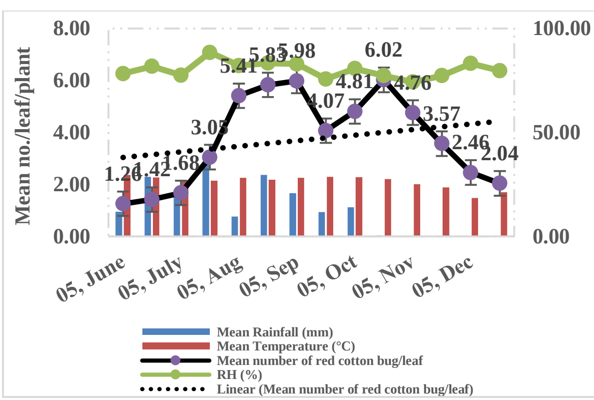


Figure 4.3.1.8 (b) Rangamati during 2015. **Figure 4.3.2.8 (e) Rangamati during 2016.**

Figure 4.3.2.8 (b & e) Seasonal red cotton bug number leaf^{-1} plant^{-1} on cotton in intercrop field at Rangamati during 2015 and 2016.



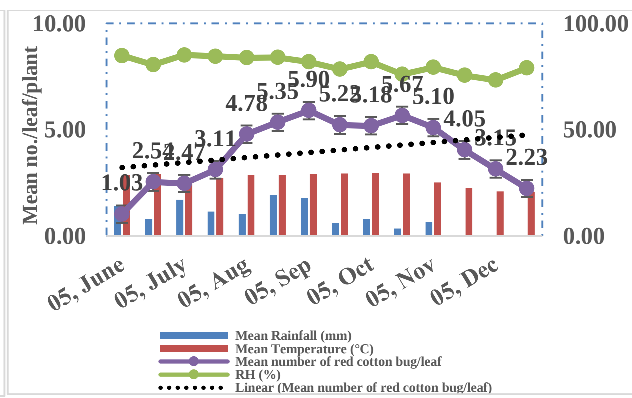


Figure 4.3.2.8 (c) at Khagrachari during 2015. **Figure x 4.3.2.8 (f) at Khagrachari during 2016.**

Figure 4.3.2.8 (c & f) Seasonal red cotton bug number leaf^{-1} plant^{-1} on cotton in intercrop field at Khagrachari during 2015 and 2016.

4.3.2.10 Dynamics of red cotton bug on intercrop cotton

During the year 2016, percentage levels of red cotton bug attacking cotton in intercrop at all hill districts are shown in Figure 4.3.2.9 (a, b and c).

Figures revealed that red cotton bug infestation on cotton boll started just at the initiation of cotton boll setting in intercrop field at all experimental fields at hill districts during the end of July or starting of August. After an initial percentage of boll staining, sharply increased infestation and reached the peak of 67.86, 60.68 and 67.17 during the end of the 3rd and 4th week of August at Rangamati, Khagrachari and Bandarban, respectively.

With increasing rainfall declined percentage of infestation sharply, thereafter prevailed their till the end of October at both experimental fields of Bandarban and Khagrachari. Whereas, after peak infestation, their presence slowly declined with decreasing mean rainfall till the later stage of the crop. Comparatively, the maximum infestations were found earlier due to the number of the cotton boll were not enough however number of bolls were increased at latter stage and consequently percentage of boll staining declined. During the end of November the maximum bolls were mature enough and red cotton bug disappear from the cotton plant or may take shelter on alternate host plants.

Overall Figure 4.3.2.8 (a, b and c) indicated the infestation also indicate those number of red cotton bugs at all hill districts were significant enough to harm the cotton boll for economic loss.

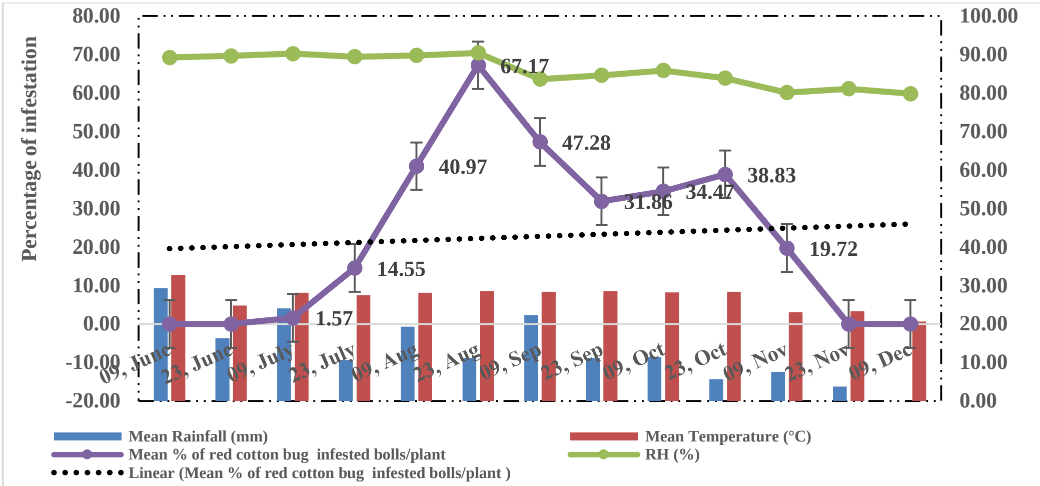


Figure 4.3.2.9 (a) Seasonal mean percentage of red cotton bug infested boll plant^{-1} on cotton in intercrop field at Bandarban during 2016.

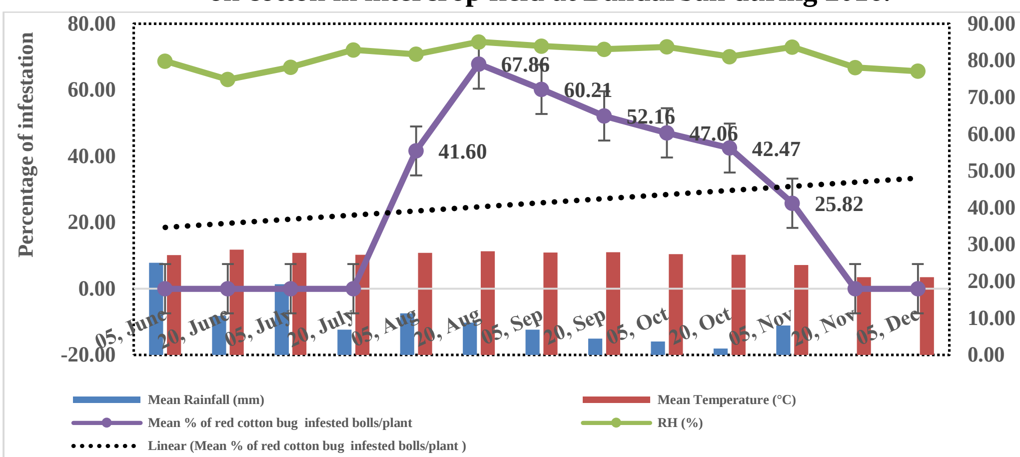


Figure 4.3.2.9 (b) Seasonal mean percentage of red cotton bug infested boll plant^{-1} on cotton in intercrop field at Rangamati during 2016.

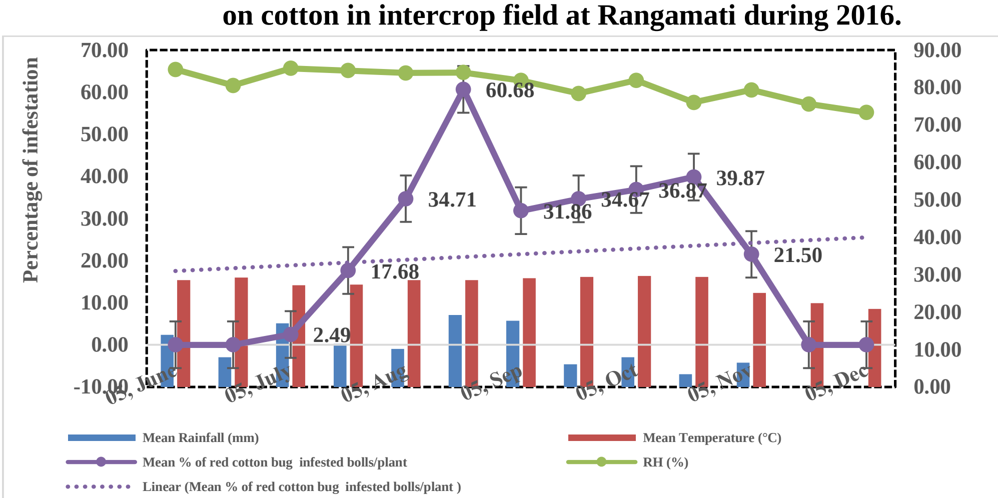


Figure 4.3.2.9 (c) Seasonal mean percentage of red cotton bug infested boll plant^{-1} on cotton in intercrop field at Khagrachari during 2016.

4.3.2.11 Dynamics of rice bug infestation on intercrop rice

During the year 2016, population levels of rice bug attacking rice grain panicle^{-1} at all hill districts are shown in Figure 4.3.2.10 (a, b and c).

The jhum farmers' traditionally harvest their rice grain just by cutting the panicle reasonably earlier than the plane land to save from falling grains and avoiding environmental calamities. Figures 4.3.2.10 (a, b and c) revealed that an insignificant percent of rice bug infestation had started from the 1st and 2nd week of August i.e., just after milking stage at Khagrachari, Rangamati and Bandarban, respectively. With decreasing mean rainfall and temperature preliminary insignificant infestation amplified throughout the panicle initiation stage and reached maximum of 5.20, 3.92 and 4.56 at the end of the 3rd and initiation of 4th week of September at Khagrachari, Rangamati and Bandarban.

The mean percentage infestation of rice bug on grains panicle^{-1} at milk initiation stage to early ripening stage were positively linear at Bandarban, Rangamati and Khagrachari.

4.3.2.12 Dynamics of rice stem borer infestation on intercrop rice

During the year 2016, infestation percentage of rice stem borer attacking rice stem at all the hill districts are shown in Figure 4.3.2.11 (a, b and c).

Figures 4.3.2.11 (a, b and c) revealed that very inadequate percentage of rice stem borer infestation started during 1st week of August after initiation of tillering stage on intercrop experimental fields at Rangamati and Khagrachari. Whereas, at Bandarban initial percent infestation was observed fifteen days later than the other two hill districts. Preliminary infestation delayed due to heavy rainfall during late May to the early month of June 2016, consequencely delay seeds sowing on intercrop fields, therefore, the rice plant arise comperatively later than the previous year at Jhum fields.

After preliminary attack with increasing tillering number infestation gradually increased and reached a peak of 8.22, 9.80 and 11.12 during the harvesting stage at the end of month September at Khagrachari, Rangamati and Bandarban correspondingly.

General inclinations of percent infestation of rice stem borer just at the initiation of tillering stage to harvesting stage during 2016 were positively linear at Bandarban, Rangamati and Khagrachari.

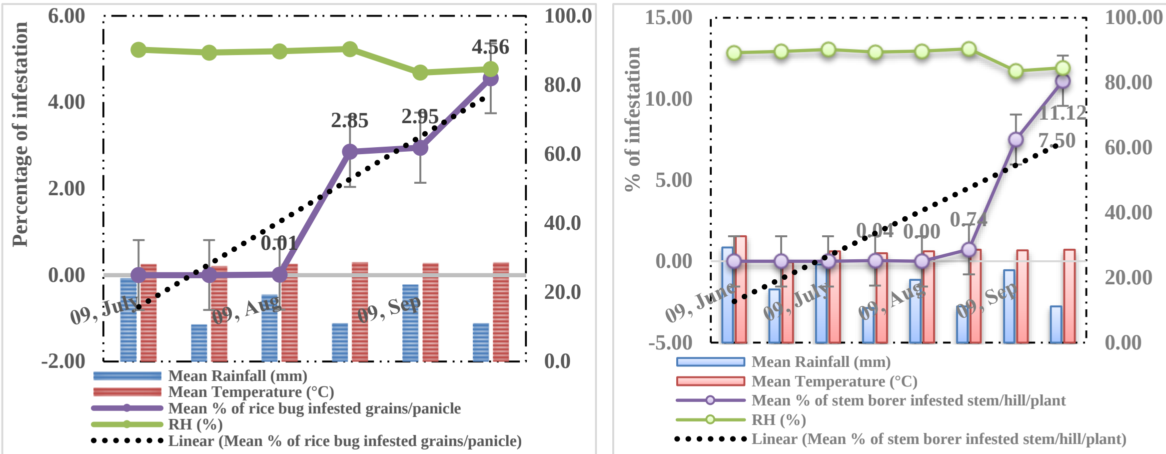


Figure 4.3.2.10 (a) and 4.3.2.11(a) Seasonal mean percentage of rice bug infested grain and stem borer infested stem in intercrop field at Bandarban during 2016.

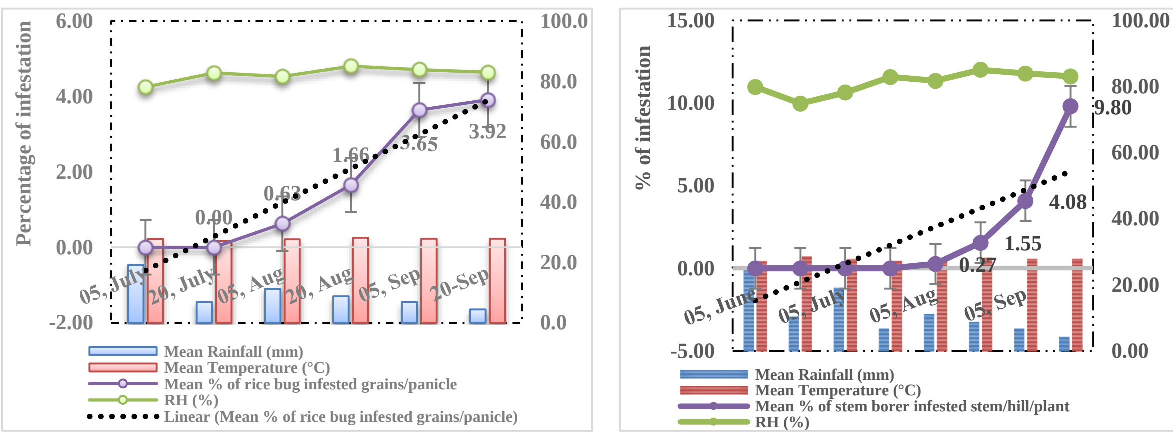


Figure 4.3.2.10 (b) and 4.3.2.11(b) Seasonal mean percentage of rice bug infested grain and stem borer infested stem in intercrop field at Rangamati during 2016.

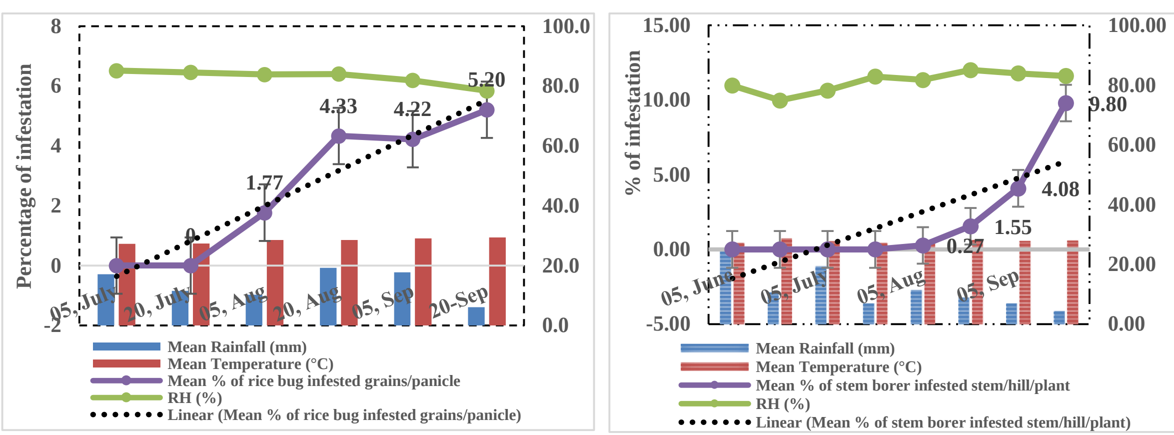


Figure 4.3.2.10 (c) and 4.3.2.11(c) Seasonal mean percentage of rice bug infested grain and stem borer infested stem in intercrop field at Khagrachari during 2016.

4.3.2.13 Dynamics of grasshopper infestation on intercrop rice

During the year 2016, population levels of grasshopper attacking intercrop rice at all hill districts are shown in Figure 4.3.2.12 (a, b and c).

Figures 4.3.2.12 (a, b and c) revealed that very limited percentage of grasshopper infestation started during 1st week of July at Rangamati and Khagrachari whereas, at Bandarban significant infestation (6.11) initiated and was revealed during 2nd week of July. In comparison to the seasonal incident during the previous year at jhum fields' infestation start one month earlier than the year 2016 at intercrop fields. Initial grasshopper infestation sharply increased in rice leaves plant^{-1} and reached a maximum of 16.08 during the 4th week of July then declined slightly on the 4th week of August and again increased their infestation and touched the second highest peak of 12.12.

Furthermore, comparatively lower infestations were observed at experimental intercrop rice crop at Rangamati and reached a peak of 3.94 on the 3rd week of August then declined infestation slowly. While at Khagrachari after insignificant initial percentage of infestation steadily increased and reached a peak of 9.13 at the time of 3rd week of August.

Among the three experimental fields, grasshopper infestation at Bandarban was more than the other two hill districts. Result exposed that rice of intercrop fields, were more encouraged to grasshopper consequently higher percentage of infestation were found during the year 2016 at all experimental fields of hill districts than the jhum field at the same year as well as the trend of infestation percentage were positively linear.

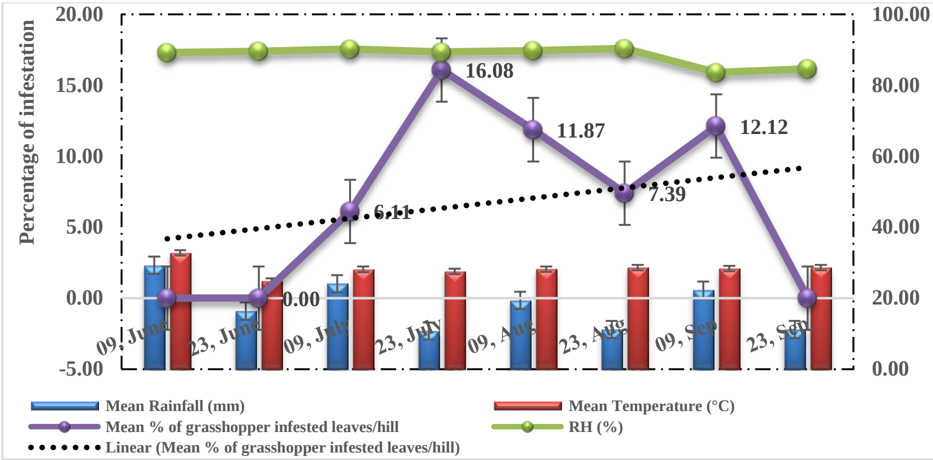


Figure 4.3.2.12 (a) Seasonal mean percentage of grasshopper infested leaf on rice in intercrop field at Bandarban during 2016.

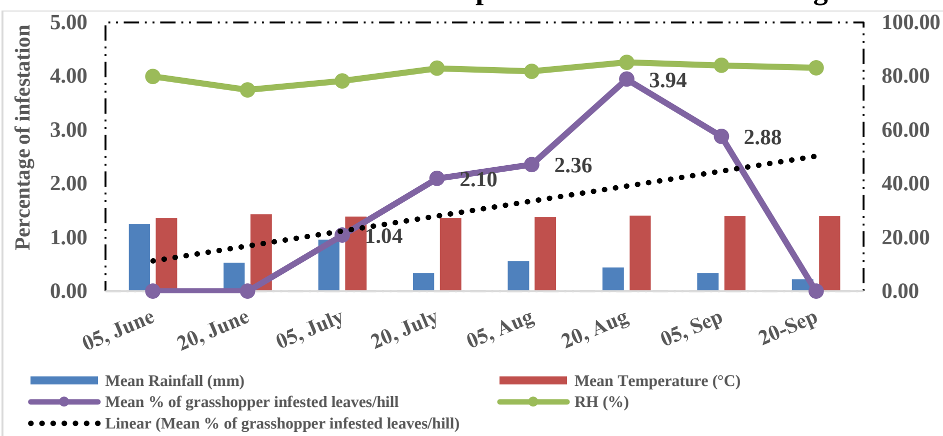


Figure 4.3.2.12 (b) Seasonal mean percentage of grasshopper infested leaf on rice in intercrop field at Rangamati during 2016.

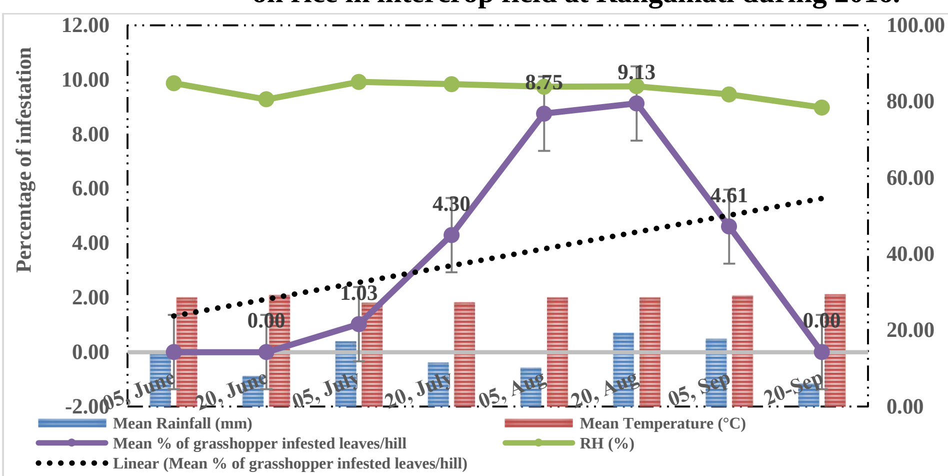


Figure 4.3.2.12 (c) Seasonal mean percentage of grasshopper infested leaf on rice in intercrop field at Khagrachari during 2016.

4.3.2.14 Dynamics of flea beetle infestation on intercrop rice

During the year 2016, infestation percentage of flea beetle attacking rice leaves at all hill districts are shown in Figure 4.3.2.13 (a, b and c).

Figures 4.3.2.13 (a, b and c) revealed that the percentage of flea beetle infestation started during 1st and 2nd week of July at Rangamati, Khagrachari and Bandarban, respectively. After initial infestation, percentage of flea beetle infestation gradually increased with an increasing number of tillering of the intercrop rice and reached maximum of 31.98, 21.41 and 32.10 during the end of 3rd and starting of 4th week of August at Rangamati, Khagrachari and Bandarban, individually. Then the infestation intensity declined and flea beetle disappeared after mid-September.

Experimental fields of Bandarban and Rangamati were much affected than Khagrachari experimental fields of hill districts. The overall percentage of flea beetle infestation in intercrop fields at all the experimental fields of hill districts, higher incursions were revealed than at jhum fields specially Khagrachari fields {Figures 4.3.1.32 (a, b and c)}. Tiny flea beetle scrapping the chlorophyll content from the tip of the leaves of rice. Consequently infested leaves look like the symptom of rice hispa infested leaf. However, these insects were not found during the survey (2014) and also the previous year survey (2015) at all my experimental fields of three districts.

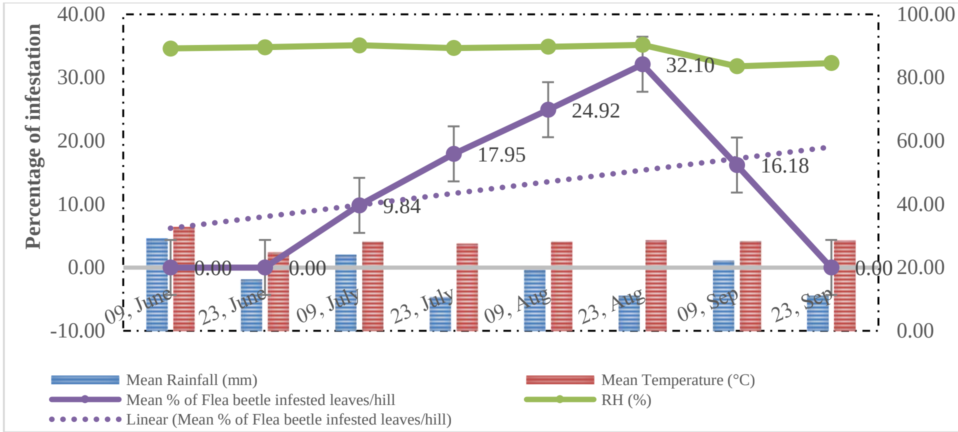


Figure 4.3.2.13 (a) Seasonal mean percentage of flea beetle infested leaf hill^{-1} on rice in intercrop field at Bandarban 2016.

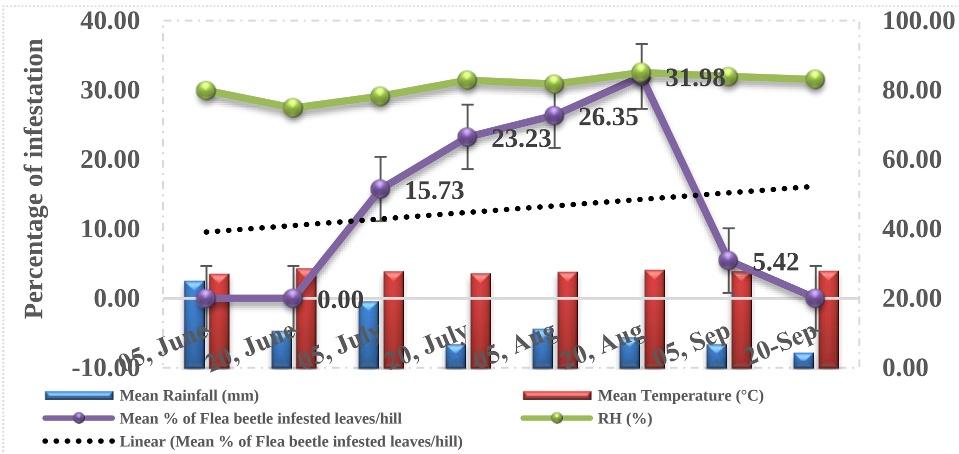


Figure 4.3.2.13 (b) Seasonal mean percentage of flea beetle infested leaf hill^{-1} on rice in intercrop field at Rangamati during 2016.

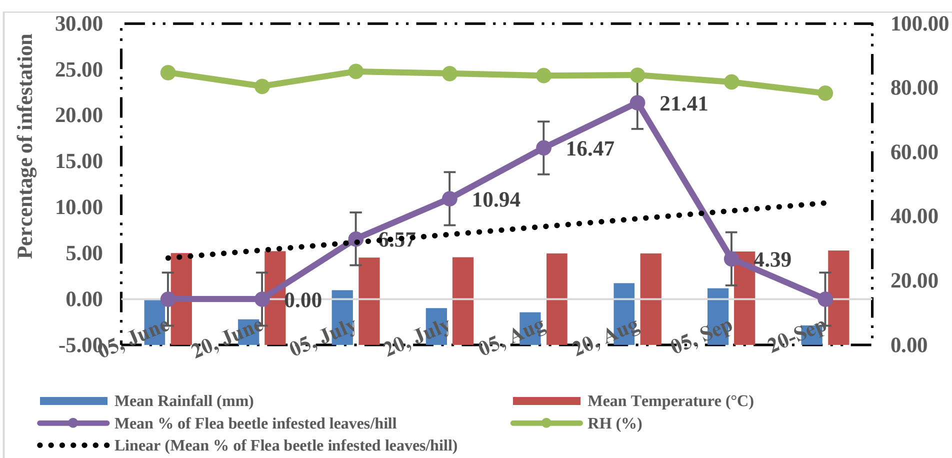


Figure 4.3.2.13 (c) Seasonal mean percentage of flea beetle infested leaf hill^{-1} on rice in intercrop field at Khagrachari 2016.

4.4 Experiment 4. Development of pest management approaches for jhum and rice-cotton intercropping system in hill districts of Bangladesh

The experiment was conducted in the farmer's fields of Bandarban, Rangamati and Khagrachari from 2015 to 2016. The main target of the experiment was to develop sustainable and eco-friendly management practices against some major and promising minor insect and mite pests of jhum and rice-cotton intercropping system in hill districts of Bangladesh. The results of the present study have been interpreted and discussed under the following sub-headings:

4.4.1 Effect of different management practices against chili insect pests on chili and its yield in jhum field at Bandarban, Rangamati and Khagrachari from 2015 to 2016

Effect of different management practices on chili fruit borer and yield of green chili varied significantly in experimental fields at Bandarban, Rangamati and Khagrachari districts from 2015 to 2016. Elaborate all the practices (1) T_1, T_2, T_3, T_4 and untreated control. (2) Also T_1, T_2, T_3, T_4, T_5 and untreated control. The results have been presented below:

4.4.1.1 Effect of different management practices on chili fruit borer on green chili

During the 1st year (2015), results indicated that considerable variation was observed among the management practices in respect of percent damaged fruits plant^{-1} (Table 4.4.1).

The highest percent damaged were recorded from the untreated control which were significantly different from all other practices at all three hill districts except treatments T_4 at Bandarban. Fruit damage was ranged 4.85 to 7.84, 0.49 to 3.50 and 4.24 to 6.76 at Bandarban, Rangamati and Khagrachari respectively. Among the experimental field of Rangamati had the lowest percent of infestation than the other two hill districts. Treatment T_3 performed the best among the other treatments and the lowest infestation (0.49) was noted which was statistically different from all other treatments and followed by T_2 (1.04), T_1 (1.36) and T_4 (2.31) at Rangamati. At Bandarban the lowest percent of fruit borer infestation (4.85) was recorded from treatment T_3 which was statistically at par of T_2 (5.23) and T_1 (5.65), but significantly different from treatment T_4 and untreated control. Similarly the lowest percent of infestation (4.24) was observed in T_3 which was statistically at par with treatment T_2 (4.77) and T_1 (5.05), and followed by T_4 (5.72) but significantly different from untreated control at Khagrachari.

The reduction of total infested fruit borer plant^{-1} over control ranged from 12.12-38.18, 34.03-86.06 and 15.38-37.26 during the whole fruiting period indicating the substantial protection from chili fruit borer at Bandarban, Rangamati and Khagrachari, correspondingly. The highest rate of reduction of infested fruit plant^{-1} over control was recorded from treatment T_3 (38.18) which was at par with T_2

(33.35), followed by T_1 (27.39) and T_4 (12.12) at Bandarban. Once again the maximum rate of reduction of infested fruit plant^{-1} over control was recorded T_3 treated plot (86.06 and 37.26) which were statistically different from all other treatments followed by T_2 (70.38 and 29.44), T_1 (61.19 and 25.34) and T_4 (34.03 and 15.38) at Rangamati and Khagrachari correspondingly.

Table 4.4.1 Effect of different management practices on chili fruits in jhum field applied against fruit borer infestation at Bandarban, Rangamati and Khagrachari during 2015

Treatments	Mean percentage of chili fruit borer infested fruit plant^{-1}			Percent reduction infestation of chili fruit borer infested fruit plant^{-1}		
	Bandar -ban	Ranga -mati	Kagra -chari	Bandar -ban	Ranga -mati	Khagra -chari
T_1 = Farmers practice	5.65 b	1.36 c	5.05 bc	27.93 b	61.19 b	25.34 b
T_2 = Spraying Actara 25 WG @ 0.5 g Liter^{-1} water at 25 days interval	5.23 b	1.04 d	4.77 c	33.35 ab	70.38 b	29.44 b
T_3 = Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water at 25 days interval	4.85 b	0.49 e	4.24 c	38.18 a	86.06 a	37.26 a
T_4 = IPM (Nappy+ Hand Weeding+ Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water apply when necessary)	6.89 a	2.31 b	5.72 b	12.12 c	34.03 c	15.38 c
T_5 = Untreated control	7.84 a	3.50 a	6.76 a	-	-	-
CV (%)	**8.66**	**7.87**	**6.83**	**12.13**	**7.74**	**13.00**

Data are the average of ten observations from 4 replications.
In a column, means followed by same letter(s) are not significantly different by Tukey's HSD test at $P<0.05$

Results presented in Table 4.4.1 revealed that the treatments T_3 and T_2 comprising spraying Voliam Flexi 300 SC @ 0.5ml Liter^{-1} water at 25 days interval and Actara 25 WG @ 0.5 gm Liter^{-1} water at 25 days interval respectively performed better than other treatments against chili fruit borer.

Results of 2016 indicated that significant variation was observed among the management practices in respect of mean percent of damaged fruits plant^{-1} (Table 4.4.2).

Comparatively lower borer infestation was observed compared to previous year (2015) on chili plant at all the experimental jhum fields of hill districts. The highest mean percentage of damage were recorded from the untreated control which were significantly different from all other treatments at all three hill districts. Fruit damage were ranged from 3.08 to 6.07, 2.92 to 5.93 and 3.25 to 5.77 at Bandarban, Rangamati and Khagrachari respectively. At Bandarban, the lowermost percent of fruit borer incursion was recorded (3.08) from T_3 treated plot which was statistically at par with treatment

T_2 (3.46) and followed by treatment T_1 (3.88), T_5 (3.96) and T_4 (5.12) but significantly varied from untreated control. The lowest (2.92) percent of infestation was observed T_3 treated plot which was at par with treatment T_2 (3.47) and followed by T_1 (3.79), T_5 (3.84) and T_4 (4.74) but significantly different from untreated control at Rangamati. Whereas, at Khagrachari Treatment T_3 performed the best and the lowest infestation was (3.25) recorded which was statically at par with the treatment T_2 (3.78) and T_1 (4.06) and followed by treatments T_5 (4.19) and T_4 (4.73).

Table 4.4.2 Effect of different management practices on chili fruits in jhum field applied against fruit borer infestation at Bandarban, Rangamati and Khagrachari during 2016

Treatments	Mean percentage of chili fruit borer infested fruit plant^{-1}			Percent reduction infestation of chili fruit borer infested fruit plant^{-1}		
	Bandar-ban	Ranga-mati	Khagra-chari	Bandar-ban	Ranga-mati	Khagra-chari
T_1 = Spraying Marshal 20 EC @ 2 ml Liter^{-1} water at 25 days interval	3.88 c	3.79 c	4.06 bcd	36.04 b	36.12 b	30.06 c
T_2 = Spraying Actara 25 WG @ 0.5 g Liter^{-1} water at 25 days interval	3.46 cd	3.47 cd	3.78 cd	43.05 ab	41.55 b	34.59 b
T_3 = Spraying Voliam Flexi 300SC @ 0.5ml Liter^{-1} water at 25 days interval	3.08 d	2.92 d	3.25 d	49.28 a	50.81 a	44.08 a
T_4 = IPM (Nappy+ Hand Weeding+ Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water apply when necessary)	5.12 b	4.74 b	4.73 b	15.64 c	20.09 c	18.55 d
T_5 = Ripcord 10 EC @ 1.0 ml Liter^{-1} water at 25 days interval	3.96 c	3.84 c	4.19 bc	34.89 b	35.30 b	27.73 c
T_6 = Untreated control	6.07 a	5.93 a	5.77 a	-	-	
CV (%)	**7.87**	**8.34**	**8.18**	**10.24**	**7.84**	**5.36**

Data are the average of ten observations from 4 replications.
In a column, means followed by same letter(s) are not significantly different by Tukey's HSD test at $P<0.05$

The reduction of total infested fruits plant^{-1} over control were ranged from 15.64-49.28, 20.09 -50.81 and 18.55-44.08 during the entire fruiting period indicating the considerable protection from chili fruit borer at Bandarban, Rangamati and Khagrachari congruently.

The highest rate of reduction of infestation of infested fruit per plant over control was recorded from treatment T_3 (49.28) which was at par to that of treatment T_2 (43.05), followed by T_1 (36.04) and T_5 (34.89) at Bandarban. The highest rate of reduction of infested fruit plant^{-1} over control was recorded from treatment T_3 (50.81) which significantly different from all other treatments and followed by T_5 (35.30), T_1 (36.12), T_2 (41.55), T_4 (20.09) at Bandarban.

While, the uppermost rate of reduction of fruit borer infestation per $plant^{-1}$ over control was veried from treatment T_3 (44.08) which is highly significant from all other treatments followed by those of treatment T_2 (34.59), T_1 (30.06) and T_5 (27.73) and T_4 (34.03) at Khagrachari. Results presented in Table 4.4.2 revealed that treatment T_3 comprising spraying of Voliam Flexi 300 SC @ 0.5ml $Liter^{-1}$ water at 25 days interval, performed the best than the other treatments against chili fruit borer. Additionally, T_2 and T_5 containing Actara 25 WG @ 0.5 g $Liter^{-1}$ water at 25 days interval and Ripcord 10 EC @ 1.0 ml $Liter^{-1}$ water at 25 days interval, respectively performed similar to each other but comparatively inferior to treatment T_3.

4.4.1.2 Effect of different management practices against unalike insect mite pests on a yield of green chili (bindu morich)

Elaborate all the practices (1) $T_{1,}$ $T_{2,}$ $T_{3,}$ T_4 and untreated contreated for the Table 4.4.3. (2) Also $T_{1,}$ $T_{2,}$ $T_{3,}$ $T_{4,}$ T_5 and untreated contreated for the Table 4.4.4. The results have been presented below:

During the 1st year (2015), results indicated that considerable variation was evident among the management practices in respect of green chili yield. (Table 4.4.3). Data revealed that all the plots treated with different treatments were significantly higher than the untreated control during both the years 2015 and 2016.

Marketable green chili yield and percent yield over untreated control in different treatments at experimental plots of Bandarban, Rangamati and Khagrachari districts are presented in Table (4.4.3). In Bandarban experimental fields during the first year (2015) demonstrated that the highest yield (199.67 g $plant^{-1}$) was recorded from T_3 (spraying Voliam Flexi 300 SC @ 0.5 ml $Liter^{-1}$ water at 25 days interval treated plot was which significantly higher than all other treatments followed by T_2 (spraying Actara 25 WG @ 0.5 g $Liter^{-1}$ water at 25 days interval) and T_4 *i.e*., IPM (Nappy+ Hand Weeding+ Spraying Voliam Flexi 300 SC @ 0.5 ml $Liter^{-1}$ water apply when necessary). Whereas in T_1 farmers practice treated plot the yield of marketable green chili was only 150.10 g $plant^{-1}$ which was numerically higher than the yield of untreated control (148.83 g $plant^{-1}$). A similar trend of yield was found at Rangamati and Khagrachari experimental jhum fields revealed that local farmers practices (T_1) failed to suppress the pest population significantly and resulted poor yield.

During the year 2015 different chemical and IPM treatment resulted the percentage of yield increase over untreated control and were ranged from 11.84-37.33 gm $plant^{-1}$ whereas the farmers practice (T_1)

failed to increase the yield over untreated control. The order of effectiveness of four treatments over untreated control was $T_3 > T_2 > T_4 > T_1$.

Table 4.4.3 Effect of different management practices applied against different insect pests and mites on green chili (bindu morich) yield in jhum field at Bandarban, Rangamati and Khagrachari during 2015

Treatments	Marketable green chili yield (g) plant^{-1}			Percent increase of yield over control		
	Bandar -ban	Ranga -mati	Khagra -chari	Bandar -ban	Ranga -mati	Khagra -chari
T_1 = Farmers practice	150.10 d	148.52 bc	145.64 d	0.85 d	4.80 d	0.95 d
T_2 = Spraying Actara 25 WG @ 0.5 g Liter^{-1} water at 25 days interval	184.43 b	178.82 a	182.94 b	23.92 b	25.58 b	26.80 b
T_3 = Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water at 25 days interval	199.67 a	193.98 a	198.14 a	34.15 a	36.22 a	37.33 a
T_4 = IPM (Nappy+ Hand Weeding+ Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water apply when necessary)	166.45 c	161.49 b	163.08 c	11.84 c	13.41 c	13.03 c
T_5 = Untreated control	148.83 d	142.40c	144.27 d	-	-	-
CV (%)	3.30	4.37	3.33	8.57	6.90	7.90

Data are the average of ten observations from 4 replications.
In a column, means followed by same letter(s) are not significantly different by Tukey's HSD test at $P<0.05$

During the second year (2016), indicated that considerable variation was observed among the management practices in respect of green chili yield. (Table 4.4.4). Result specified that marketable green chili yield at the experimental field of Bandarban was the highest (199.67 g plant^{-1}) from the treatment T_3 (spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water at 25 days interval), which was statistically different from all other treatments. The second highest yield (184.48 g plant^{-1}) was recorded from treatment T_2 (spraying Actara 25 WG @ 0.5 g Liter^{-1} water at 25 days interval) which was statistically identical to that of T_1 (spraying Marshal 20 EC @ 2 ml Liter^{-1} water at 25 days interval) and was followed by T_5 (Ripcord 10 EC @ 1.0 ml Liter^{-1} water at 25 days interval) and T_4 *i.e.*, IPM (Nappytrap+ Hand Weeding+ Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water apply when necessary).

Whereas the yield (153.38 g plant^{-1}) of untreated control was the lowest which was statistically at par with treatments T_4 and T_5. Result revealed that Ripcord 10 EC @ 1.0 ml Liter^{-1} water was not effective to suppress the insect pest population. In addition the IPM practice, was not familiar to the Jhumian people to use the different IPM tools efficiently. A similar trend of yield was found at

Rangamati and Khagrachari experimental jhum fields and was revealed that the persistent chemical treatments (T_3, T_2 and T_1) performed better in jhum field during the monsoon.

Table 4.4.4 Effect of different management practices applied against different insect pests and mites on green chili (Bindu morich) yield in jhum field at Bandarban, Rangamati and Khagrachari during 2016

Treatments	Marketable green chili yield (g) plant^{-1}			Percent increase of yield over control		
	Bandar -ban	Ranga -mati	Khagra -chari	Bandar -ban	Ranga -mati	Khagra -chari
T_1 = Spraying Marshal 20 EC @ 2 ml Liter^{-1} water at 25 days interval	175.00 bc	169.36 bc	173.55 bc	14.10 c	15.13 c	14.23 c
T_2 = Spraying Actara 25 WG @ 0.5 g Liter^{-1} water at 25 days interval	184.48 b	178.91 ab	183.10 b	20.52 b	21.10 b	20.52 b
T_3 = Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water at 25 days interval	199.71 a	194.07 a	198.29 a	30.21 a	31.36 a	30.52 a
T_4 = IPM (Nappy+ Hand Weeding+ Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water apply when necessary)	166.50 cd	161.58 cd	163.23 cd	8.55 d	9.37 d	7.44 d
T_5 = Ripcord 10 EC @ 1.0 ml Liter^{-1} water at 25 days interval	164.85 cd	158.28 cd	161.69 cd	7.48 d	7.14 d	6.43 d
T_6 = Untreated control	153.38 d	147.74 d	151.93 d	-	-	-
CV (%)	3.44	4.37	3.68	10.61	12.17	9.15

Data are the average of ten observations from 4 replications.
In a column, means followed by same letter(s) are not significantly different by Tukey's HSD test at $P<0.05$

During the year 2016 different chemical and IPM treatments showed that percentage of yield increase over untreated control was recorded as 6.43 -31.36 g plant^{-1}. The order of effectiveness of five treatments over untreated control was $T_3 > T_2 > T_1 > T_4 > T_5$. Result also indicated that chemical Ripcord 10 EC @ 1.0 ml Liter^{-1} water (T_5) was not effective because the jhum cultivation depends on monsoon season in Bangladesh when maximum rainfall was recorded. Consequently non-persistent chemical easily washed away after application.

4.4.2 Effect of different management practices against maize grasshopper on maize plants and yield in jhum field at Bandarban, Rangamati and Khagrachari from 2015 to 2016

Effect of different management practices against among maize and cob yield varied significantly experimental fields at Bandarban, Rangamati and Khagrachari districts from 2015 to 2016. The results have been presented below:

4.4.2.1 Effect of different management practices against grasshopper on maize

Results of the year 2015, indicated significant variation among the management practices in respect of percent maize grasshopper infested leaves plant^{-1} (Table 4.4.5) was observed.

Table 4.4.5 Effect of different management practices on maize leaves in jhum field used against grasshopper infestation at Bandarban, Rangamati and Khagrachari during 2015

Treatments	Mean percentage maize grass hopper infested leaves plant^{-1}			Percent reduction of maize grass hopper infested leaves plant^{-1}		
	Bandar -ban	Ranga -mati	Khagra -chari	Bandar -ban	Ranga -mati	Khagra -chari
T_1 = Farmers practice	38.34 b	55.70 b	40.63 c	31.24 a	20.49 b	35.59 b
T_2 = Spraying Actara 25WG @ 0.5 g Liter^{-1} water at 25 days interval	34.14 b	55.40 b	34.68 d	38.78 a	20.92 b	45.03 a
T_3 = Spraying Voliam Flexi 300SC @ 0.5ml Liter^{-1} water at 25 days interval	36.32 b	48.65 c	35.36 d	34.88 a	30.56 a	43.96 ab
T_4 = IPM (Nappy+ Hand Weeding+ Spraying Voliam Flexi 300SC @ 0.5 ml Liter^{-1} water apply when necessary)	36.48 b	56.37 b	48.83 b	34.58 a	19.54 b	22.60 c
T_5 = Untreated control	55.76 a	70.05 a	63.09 a	-	-	-
CV (%)	**5.08**	**4.44**	**5.03**	**11.29**	**14.22**	**10.33**

Data are the average of ten observations from 4 replications.
In a column, means followed by same letter(s) are not significantly different by Tukey's HSD test at $P<0.05$

The maximum percentage of damaged was recorded from the untreated control which was statistically unlike all other treatments at all three hill districts. Leaves damaged was ranged from 34.14 to 55.76, 48.65 to 70.05 and 34.68 to 63.09 at Bandarban, Rangamati and Khagrachari, individually. At Bandarban the lowest percent of leaf, infestation was recorded (34.14) from treatment T_2 which was statistically identical to that of treatments T_3 (36.32), T_4 (36.48) and T_1 (38.34).

However, the lowest (48.65) percent infestation was observed from treatment T_3 which was significantly different from all other treatments and followed by treatments T_2 (55.40), T_1 (55.70), and T_4 (56.37) at Rangamati. Treatment T_2 performed the best compared other treatment and the lowest infestation was 34.68 which was statistically similar to that of treatment T_3 (35.36) and followed by T_1 (40.63) and then T_4 (48.83), at Khagrachari.

The reduction of total infested maize leaf over control was ranged from 31.24-38.78, 19.54 -30.56 and 22.60-45.03 during the whole vegetative and before cob forming stage presenting the extensive protection from grasshopper at Bandarban, Rangamati and Khagrachari respectively.

The highest percentage of reduction of infested leaves plant^{-1} over control was recorded from treatment T_2 (38.78) which was at par but numerically lower than treatments T_3 (34.88), T_4 (34.58) and T_1 (31.24) at Bandarban. The uppermost reduction of infestation plant^{-1} over control was recorded from treatment T_3 (30.56) which was significantly different from all other treatments and followed by those treatments T_2 (20.92), T_1 (20.49) and T_4 (19.54) at Rangamati. Despite the fact, the highest rate of decrease of infested leaves plant^{-1} over control was recorded from treatment T_2 (45.03) which was significantly comparable with treatment T_3 (43.96) but statistically unlike from all other treatments and followed by those treatments T_1 (35.59) and T_4 (22.60) at Khagrachari.

During the year 2016, results indicated that, significant variation was among the management practices in respect of percent maize grasshopper infested leaves plant^{-1} (Table 4.4.6). The highest percentage damage were recorded from the untreated control which were statistically unlike from all other treatments at all three hill districts. Leave injury were ranged (42.47 to 67.72), (43.68 to 65.08) and (46.04 to 74.44) at Bandarban, Rangamati and Khagrachari respectively. At Bandarban the lowermost percent leave infestation was recorded (46.10) from treatment T_5 which was statistically identical with that of treatments T_2 (46.10), T_3 (48.27), T_4 (48.44) which was statistically different from T_1 (50.30). Conversely, the lowest (43.65) mean percent infestation was observed from treatment T_5 which was significantly at par with treatment T_3 (43.68) but different from other treatments T_2 (50.43), T_1 (50.72), and T_4 (51.39) at Rangamati. Treatment T_2 performed the best among the other treatments and the lowest mean infestation was (46.04) noted which was statistically similar to that of treatments T_3 (46.71) and T_5 (48.09) but statistically different from other treatment and followed by T_1 (51.99) and then T_4 (60.19) at Khagrachari.

The reduction of infested leaves plant^{-1} over control ranged from (25.73 -37.28), (21.03 -32.93) and (19.15-38.16) during the whole vegetative till the begening of cob forming period representing the satisfactory protection from grasshopper at Bandarban, Rangamati and Khagrachari respectively. The highest rate of reduction of infested leaves plant^{-1} over control was recorded from treatment T_5

(37.28) which was at paer but numerically lower with treatment T_2 (31.93) but significantly different from treatments T_3 (28.71), T_4 (28.47) and T_1 (25.73) at Bandarban.

Table 4.4.6 Effect of different management practices on maize leaves in jhum field applied against grasshopper infestation at Bandarban, Rangamati and Khagrachari during 2016

Treatments	Mean percentage maize grass hopper infested leaves plant^{-1}			Percent reduction of maize grass hopper infested leaves plant^{-1}		
	Bandar-ban	Ranga-mati	Khagra-chari	Bandar-ban	Ranga-mati	Khagra-chari
T_1 = Spraying Marshal 20 EC @ 2 ml Liter^{-1} water at 25 days interval	50.30 b	50.72 b	51.99 c	25.73 b	22.06 b	30.16 b
T_2 = Spraying Actara 25 WG @ 0.5 g Liter^{-1} water at 25 days interval	46.10 bc	50.43 b	46.04 d	31.93 ab	22.51 b	38.16 a
T_3 = Spraying Voliam Flexi 300 SC @ 0.5ml Liter^{-1} water at 25 days interval	48.27 bc	43.68 c	46.71 cd	28.71 b	32.89 a	37.25 a
T_4 = IPM (Nappy+ Hand Weeding+ Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water apply when necessary)	48.44 bc	51.39 b	60.19 b	28.47 b	21.03 b	19.15 c
T_5 = Ripcord 10 EC @ 1.0 ml Liter^{-1} water at 25 days interval	42.47 c	43.65 c	48.09 cd	37.28 a	32.93 a	35.40 ab
T_6 = Untreated control	67.72 a	65.08 a	74.44 a	-	-	-
CV (%)	**5.56**	**5.33**	**4.64**	**10.50**	**13.68**	**9.60**

Data are the average of ten observations from 4 replications.
In a column, means followed by same letter(s) are not significantly different by Tukey's HSD test at *$P<0.05$*

The highest rate of reduction of infestation of infested leaves plant^{-1} over control was recorded from treatment T_5 (32.93) which was at par T_3 (32.89) but significantly different from other treatments and followed by those of treatments T_4 (21.03), T_1 (22.06) and T_2 (22.51) at Rangamati. Even with the maximum percentage of reduction of infestation over control was recorded from treatment T_2 (38.16) which was significantly comparable with that of treatment T_3 (37.25) followed by treatment T_5 (35.40) but statistically different from treatment T_1 (30.16) and followed by treatment T_4 (19.15) at Khagrachari.

Results presented in Table 4.4.6 revealed that treatments T_2 and T_3, comprising spraying Actara 25WG @ 0.5 g liter^{-1} water at 25 days interval and ripcord 10EC @ 1.0 ml liter^{-1} water at 25 days interval and Volume Flexi 300 SC @ 0.5 ml liter^{-1} water at 25 days interval performed the best than other treatments respectively against grasshoppers. Furthermore, T_5 having Ripcord 10 EC @ 1.0 ml Liter^{-1} water at 25 days interval performed similar to the above mention treatments.

4.4.2.2 Effect of different management practices on used against maize seed yield in jhum

During the 1st year (2015), it was indicated that considerable variation was observed among the management practices in respect of maize seed yield plant^{-1} (Table 4.4.7).

Table 4.4.7 Effect of different management practices on maize seed yield in jhum field applied against at Bandarban, Rangamati and Khagrachari during 2015

Treatments	Marketable maize seed yield (g) plant^{-1}			Percent increase of yield over control		
	Bandar -ban	Ranga -mati	Khagra -chari	Bandar -ban	Ranga -mati	Khagra -chari
T_1 = Farmers practice	118.77 bc	118.69 ab	119.14 ab	1.34 c	1.04 d	0.98 c
T_2 = Spraying Actara 25 WG @ 0.5 g Liter^{-1} water at 25 days interval	121.86 a	122.13 a	123.10 a	1.58 c	1.79 c	2.35 b
T_3 = Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water at 25 days interval	121.12 ab	121.63 ab	121.00 ab	3.34 b	3.97 a	2.57 b
T_4 = IPM (Nappy+ Hand Weeding+ Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water apply when necessary)	119.06 bc	119.58 ab	120.16 ab	3.98 a	3.53 b	3.81 a
T_5 = Untreated control	117.20 c	117.47 b	117.98 b	-	-	-
CV (%)	1.92	1.55	1.68	10.63	7.14	5.28

Data are the average of ten observations from 4 replications.
In a column, means followed by same letter(s) are not significantly different by Tukey's HSD test at $P<0.05$

Results revealed that all the plots treated with different treatments produced significantly higher maize seed yield plant^{-1} than the untreated control both years i.e., 2015 and 2016. Marketable maize seed yield and percent of yield increase over untreated control in different treatments at experimental plots of Bandarban, Rangamati and Khagrachari districts are presented in Table (4.4.7 and 4.4.8). In Khagrachari experimental fields during the first year (2015) presented the highest yield (123.10 g plant^{-1}) in T_2 (Spraying Actara 25 WG @ 0.5 g Liter^{-1} water at 25 days interval) which treated plot was significantly at par with treatments T_3, T_4 and T_1 but statistically different from untreated control.

Similar yield trend were observed in the experimental fields of Rangamati but at Bandarban again the highest yield (121.86 g plant^{-1}) was recorded from T_2 which was statistically at par with T_3 (spraying Voliam Flexi 300 SC @ 0.5ml Liter^{-1} water at 25 days interval) and followed by T_4 and T_1 but significantly differently from untreated control.

Table 4.4.8 Effect of different management practices applied against on maize seed yield in jhum field at Bandarban, Rangamati and Khagrachari during 2016

Treatments	Marketable maize seed yield (g) plant^{-1}			Percent increase of yield over control		
	Bandar -ban	Ranga -mati	Khagra -chari	Bandar -ban	Ranga -mati	Khagra -chari
T_1 = Spraying Marshal 20 EC @ 2 ml Liter^{-1} water at 25 days interval	121.69 a	122.22 a	120.83 a	3.76 a	4.66 a	3.16 b
T_2 = Spraying Actara 25 WG @ 0.5 g Liter^{-1} water at 25 days interval	118.89 ab	119.67 ab	119.99 a	1.37 c	2.23 b	2.44 b
T_3 = Spraying Voliam Flexi 300 SC @ 0.5ml Liter^{-1} water at 25 days interval	120.94 ab	121.72 ab	118.46 a	3.13 b	3.98 a	1.14 c
T_4 = IPM (Nappy+ Hand Weeding+ Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water apply when necessary)	118.60 ab	118.38 ab	122.92 a	1.13 c	1.13 c	4.95 a
T_5 = Ripcord 10 EC @ 1.0 ml Liter^{-1} water at 25 days interval	118.87 ab	119.77 ab	120.13 a	1.35 c	2.32 b	2.56 b
T_6 = Untreated control	117.28 b	117.06 b	117.21 a	-	-	-
CV (%)	1.52	1.78	2.10	12.90	15.95	13.67

Data are the average of ten observations from 4 replications.

In a column, means followed by same letter(s) are not significantly different by Tukey's HSD test at $P<0.05$

During the year 2015 different chemicals and IPM treatments had percent yield increase over untreated control were ranged 0.98-3.98 g plant^{-1} which was not adequate increase of yield over untreated control. The major insect pest was grasshopper which mainly feed on foliage but not damage cob as well as corn borer infestation was very insignificant during both years in the jhum field. The order of effectiveness of four treatments over untreated control was $T_2 > T_3 > T_4 > T_1$.

In the second year (2016) showed considerable variations among the management practices in respect of maize seed yield (Table 4.4.8). Result indicated that marketable maize seed yield at experimental field of Khagrachari was the highest (122.92 g plant^{-1}) and was recorded from treatment T_4 *i.e.*, IPM

(Nappy+ Hand Weeding+ Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water apply when necessary), which was statistically identical with all other treatments but numerically little higher than other. Whereas at Bandarban and Rangamati T_1 (spraying Marshal 20 EC @ 2 ml Liter^{-1} water at 25 days interval) had the highest maize seed yield 121.69 g plant^{-1} and 122.22 g plant^{-1} respectively and significantly different from untreated control but at par with other treatments. In the year 2015 different chemicals and IPM treatments resulted yield increase over untreated control were recorded only (1.13-4.95 g plant^{-1}) which was not adequate. But maize plant and the cob were sometimes harshly damaged by Fox and cob eating birds. Study considered only insect and mite as pests'.

4.4.3 Effect of different management practices applied against fruit fly on marpha fruits and yield in jhum field at Bandarban, Rangamati and Khagrachari during 2015 to 2016

Effect of different management practices used against fruit fly on marpha fruits varied significantly in experimental fields at Bandarban, Rangamati and Khagrachari districts during 2015 to 2016. The results have been presented below:

4.4.3.1 Effect of different management practices against fruit fly on marpha

During the year 2015, results showed that significant variation were pragmatic among the management practices in admiration of percent of infested fruits plan^{-1} (Table 4.4.9).

The highest mean percent of fruit fly infestation were (36.67, 40.24 and 32.03) recorded from untreated control plot from experimental jhum marpha crop at Bandarban, Rangamati and Khagrachari, respectively. The percent of infested fruits plan^{-1} meanwhile untreated control were significantly at par with treatments T_1 (28.26) and T_2 (28.85) treated plots at Bandarban however, at Rangamati was not dissimilar with treatments T_4 (34.51) and T_2 (35.48) treated plots. Results of untreated control were statistically indistinguishable with treatments T_1 (26.12) and T_4 (27.12) at Khagrachari. Fruits damage were ranged from 24.85 to 36.67, 25.50 to 40.24 and 21.80 to 32.03 at Bandarban, Rangamati and Khagrachari, respectively. At Bandarban the lowest percent of fruit fly infestation was recorded (24.85) from treatment T_3 which was statistically comparable with treatments T_4 (27.25) followed by T_1 (28.26) and T_2 (28.85). Similarly the lowermost (25.50) percent of infestation was observed from treatment T_3 which was at par with treatments T_1 (30.94), on the other hand significantly different from T_4 (34.51), and T_2 (35.48) at Rangamati. Conversely, at Khagrachari the lowest (21.80) mean percent of infestation was observed from treatment T_3 which was at par but numerically higher infestation from treatments T_2 (25.21) followed by T_1 (26.12) and T_4 (27.12) treated plots.

The reduction of total infested fruits plan^{-1} over control was ranged from (21.32-32.23), (11.84-36.64) and (15.33-31.94) during the entire fruiting period providing protection from marpha fruit borer at Bandarban, Rangamati and Khagrachari, congruently. The highest percent reduction of infestation over control was documented from treatment T_3 (32.23) which was statistically different from all other treatments at Bandarban. The subsequent uppermost rate of reduction (25.69) was detected from treatment T_4 which was ominously equal with the treatment T_1 (22.92) followed by treatment T_2 (21.32).

Table 4.4.9 Effect of different management practices on marpha fruits in jhum field applied against fruit fly infestation at Bandarban, Rangamati and Khagrachari during 2015

Treatments	Mean percentage infestation of marpha fruit fly plant^{-1}			Percent reduction infestation of marpha fruit fly plant^{-1}		
	Bandar -ban	Ranga -mati	Khagra -chari	Bandar -ban	Ranga -mati	Khagra -chari
T_1 = Farmers practice	28.26 ab	30.94 bc	26.12 ab	22.92 bc	23.12 b	18.46 bc
T_2 = Spraying Actara 25WG @ 0.5 g Liter^{-1} water at 25 days interval	28.85 ab	35.48 ab	25.21 b	21.32 c	11.84 c	21.32 b
T_3 = Spraying Voliam Flexi 300SC @ 0.5ml Liter^{-1} water at 25 days interval	24.85 b	25.50 c	21.80 b	32.23 a	36.64 a	31.94 a
T_4 = IPM (Nappy+ Hand Weeding+ Spraying Voliam Flexi 300SC @ 0.5 ml Liter^{-1} water apply when necessary)	27.25 b	34.51 ab	27.12 ab	25.69 b	14.26 c	15.33 c
T_5 = Untreated control	36.67 a	40.24 a	32.03 a	-	-	-
CV (%)	**13.84**	**11.31**	**10.95**	**6.66**	**7.13**	**10.77**

Data are the average of ten observations from 4 replications.

In a column, means followed by same letter(s) are not significantly different by Tukey's HSD test at $P<0.05$

The highest percent of decrease of infested fruit plan^{-1} over control was recorded from treatment T_3 (36.64) treated plotwhich was significantly different from all other treatments at Rangamati. Again the second highest rate of reduction over control (26.30) was observed from treatment T_1 which was significantly varied from the treatments T_4 (14.26) followed by treatment T_2 (11.84) which performed the lowest reduction at Rangamati. Results indicated that the treatment T_2 having application of actara 25.WG @ 0.5 g liter^{-1} water at 25 days interval was not effective against fruit fly infestation on jhum squash (marpha) The uppermost percentage of reduction of infested fruit plan^{-1} over control was recorded from treatment T_3 (31.94) which significantly different from all other treatments but the second highest reduction was (21.32) from the treatment T_2 which was not differed statistically from the treatment T_1 (18.46) and followed by T_4 (15.33) at Khagrachari.

In the year 2016, results showed extensive variation among the management practices in respect of percent infested fruits plan^{-1} (Table 4.4.10).The highest percent infestation were (33.10, 35.37 and 26.58) recorded from untreated control plot from experimental jhum marpha crop at Bandarban, Rangamati and Khagrachari, respectively although percent of infestation were statistically dissimilar from all other treatments at all three hill districts.

At Bandarban the bottommost percent fruit fly infestation was recorded (21.29) from treatment T_3 which was statistically identical with treatments T_4 (23.68) but statistically not the similar from other treatments. Although treatment (T_4) performed the second lowest infestation but not statistically differed from other treatments like T_1 (24.70), T_5 (25.08) and T_2 (25.29). Similarly the lowermost (20.63) percent infestation was observed from treatment T_3 which was at par with treatments T_5 (23.65) but significantly different from other treatments. The second lowest infestation was observed from treatment T_5 treated plot which was significantly equal with the treatment T_1 (26.07) followed by treatments T_4 (29.64) and T_2 (30.61) at Rangamati. Nevertheless, at Khagrachari the lowest (16.34) percent of infestation was observed from treatment T_3 which was at par but numerically to some extent higher infestation from the treatments T_2 (19.75) followed by T_1 (20.67), T_5 (21.62) and T_4 (21.67).

The reduction of total infested fruits plan^{-1} over control ranged from (23.62-35.70), (13.47-41.68) and (18.48-36.75) during the entire fruiting period indicating the predictable protection from marpha fruit borer at Bandarban, Rangamati and Khagrachari, congruently. The highest percent of reduction of infested fruit plan^{-1} over control was recorded from treatment T_3 (35.70) which was statistically different from all others treatments at Bandarban. The second highest rate of reduction was (28.46) observed from treatment T_4 which was significantly alike with the treatments T_5 (24.23) and T_1 (25.39) followed by treatment T_2 (23.62). Similarly the highest reduction of infestation over control was recorded from treatment T_3 (41.68) which was significantly different from all other treatments at Rangamati. Once more the second highest percent of reduction over control (33.13) was observed from treatment T_5 which was significantly different with the treatments T_1 (26.30), T_4 (16.22) followed by treatment T_2 (13.47) which performed the lowest reduction over control at Rangamati. Result indicated that among the treatments wide and significant variation were observed. The highest percent of reduction of infested fruit plan^{-1} over control was recorded from the treatment T_3 (36.75) which significantly different from all other treatments but the second highest reduction was (26.95) from the treatment T_2 which was significantly at par with treatment T_1 (22.75) then followed by T_5 (18.65) and T_4 (18.48) at Khagrachari.

Table 4.4.10 Effect of different management practices on marpha fruits in jhum field applied against fruit fly infestation at Bandarban, Rangamati and Khagrachari during 2016

Treatments	Mean percentage infestation of marpha fruit fly plant^{-1}			Percent reduction infestation of marpha fruit fly plant^{-1}		
	Bandar -ban	Ranga -mati	Khagra -chari	Bandar -ban	Ranga -mati	Khagra -chari
T_1 = Spraying Marshal 20 EC @ 2 ml Liter^{-1} water at 25 days interval	24.70 b	26.07 cd	20.67 b	25.39 bc	26.30 c	22.75 bc
T_2 = Spraying Actara 25 WG @ 0.5 g Liter^{-1} water at 25 days interval	25.29 b	30.61 b	19.75 bc	23.62 c	13.47 d	26.95 b
T_3 = Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water at 25 days interval	21.29 c	20.63 e	16.34 c	35.70 a	41.68 a	36.75 a
T_4 = IPM (Nappy+ Hand Weeding+ Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water apply when necessary)	23.68 bc	29.64 bc	21.67 b	28.46 b	16.22 d	18.48 c
T_5 = Ripcord 10 EC @ 1.0 ml Liter^{-1} water at 25 days interval	25.08 b	23.65 de	21.62 b	24.23 bc	33.13 b	18.65 c
T_6 = Untreated control	33.10 a	35.37 a	26.58 a	-	-	-
CV (%)	**5.70**	**6.96**	**7.84**	**6.85**	**7.02**	**10.28**

Data are the average of ten observations from 4 replications.
In a column, means followed by same letter(s) are not significantly different by Tukey's HSD test at $P<0.05$

Results presented in Table 4.4.10 revealed that treatment T_3 having spraying voliam flexi 300 SC @ 0.5ml litre^{-1} water at 25 days interval and actara 25 WG @ 0.5 g liter^{-1} water at 25 days interval performed better than other treatments at all experimental fields of hill districts during 2015 and 2016. Other chemical treatments were failed to achieve satisfactory results among the three hill districts due to internal feeding behaviour of the insect and anough variation of rainfall and these may reduce their efficacy on fruit fly control.

4.4.3.2 Effect of different management practices applied against marpha fruit yield in jhum

In 2015, yield result showed the substantial dissimilarity among the management practices in respect of marpha fruit yield plant^{-1} (Table 4.4.11). Data uncovered that all the different plots treated with different practices were significantly higher marketable fruit yield plant^{-1} (kg) than the untreated control obtained in both 2015 and 2016. Marketable Marpha fruit yield and percentage of yield over untreated control in different treatments at experimental plots of Bandarban, Rangamati and Khagrachari districts are presented in Table (4.4.11 and 4.4.12).

Table 4.4.11 Effect of different management practices used against marpha fruit yield in jhum field at Bandarban, Rangamati and Khagrachari during 2015

Treatments	Marketable marpha fruit yield (kg) plant^{-1}			Percent increase of yield over control		
	Bandar-ban	Ranga-mati	Khagra-chari	Bandar-ban	Ranga-mati	Khagra-chari
T_1 = Farmers practice	1.18 b	1.14 bc	1.12 cd	2.66 c	11.04 d	9.29 d
T_2 = Spraying Actara 25 WG @ 0.5 g Lit.$^{-1}$ water at 25 days interval	1.19 b	1.12 abc	1.13 ab	7.47 b	8.97 c	10.85 b
T_3 = Spraying Voliam Flexi 300 SC @ 0.5 ml Lit.$^{-1}$ water at 25 days interval	1.29 a	1.21 a	1.18 a	16.60 a	17.91 a	16.31 a
T_4 = IPM (Nappy+ Hand Weeding+ Spraying Voliam Flexi 300 SC @ 0.5 ml Lit.$^{-1}$ water apply when necessary)	1.19 b	1.15 ab	1.10 bc	7.25 b	12.98 b	8.11 c
T_5 = Untreated control	1.12 b	1.03 c	0.98 d	-	-	-
CV (%)	3.25	4.85	3.00	8.90	7.95	8.56

Data are the average of ten observations from 4 replications.
In a column, means followed by same letter(s) are not significantly different by Tukey's HSD test at $P<0.05$

In Bandarban experimental fields of the year 2015 confirmed that the highest yield (1.29 kg plant^{-1}) was recorded from T_3 (spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water at 25 days interval) treated plot which was a significantly different from all other treatments. Whereas at Rangamati the highest fruit yield (1.21 kg plant^{-1}) was recorded from the same treatment (T_3) which was statistically identical with that of treatments T_4 and T_2 but statistically different from treatment T_1 and untreated control. At the experimental jhum field of Khagrachari again the treatment T_3 provided maximum yield plant^{-1} but comparatively lower yield than the other two districts experimental jhum fields and was statistically at par with the treatment T_2 and statistically different from all other treatments. Untreated control plots at all experimental fields of three hill districts provided the lowest yield due to comparatively higher fruit fly infestation.

In 2015 different chemicals and IPM treatments the percent yield increase over untreated control were ranged from (2.66-17.91 kg plant^{-1}) but it was not an adequate increase in the yield over untreated control. The order of effectiveness of four management practices over untreated control were $T_3 > T_4 > T_2 > T_1$.

The study of the second year (2016) showed that considerable variation among the management practices in respect of marpha fruit yield (Table 4.4.12). Result specified that marketable marpha fruit yield at the experimental field of Khagrachari was highest (1.31 kg plant^{-1}) and was recorded from treatment T_3 (spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water at 25 days interval) treated plot which was statistically identical with that of treatments T_2 and T_1 but statistically different from other treatments. A similar trend of results were observed from Bandarban and Rangamati experimental fields but last year fruit yield increased at Khagrachari experimental fields comparatively higher than the other two hill districts. This was the consequences of lower fruit infestation at Khagrachari than the other two districts. At all experimental jhum fields the lowest marpha fruit yield (1.09, 1.08 and 1.01 kg plant^{-1}) were observed from untreatment control plots at Khagrachari, Bandarban and Rangamati, respectively these were statistically identical with untreated control but different from all other treatments.

The major insect pest was fruit fly which was intimidating pests of several crops specially cucurbitaceous crops. Comparatively the lower infestation was observed at jhum crop by this notorious pest than the hill valley crops. Insecticides sometimes might not very effective to suppress infestation of fruit fly due to reduction of efficacy by washing out from treated plants. Jhum cultivation practice mainly in Bangladesh during the monsoon season thus frequent rainfall occur and cause insecticides less effective. The Jhumian people harvested the marpha fruit at an early stage for selling as a vegetable as well as for personal cocking. During the year 2016 different chemicals and IPM treatments result an adequate yield increase over untreated control and was ranged from (7.10-21.36 kg plant^{-1}). The order of effectiveness of four practices over untreated control were $T_3 > T_2 > T_1 > T_4 > T_5$.

Table 4.4.12 Effect of different management practices applied against on marpha fruit yield in jhum field at Bandarban, Rangamati and Khagrachari during 2016

Treatments	Marketable Marpha fruit yield (kg) plant^{-1}			Percent increase of yield over control		
	Bandar -ban	Ranga -mati	Khagra -chari	Bandar -ban	Ranga -mati	Khagra -chari
T_1 = Spraying Marshal 20 EC @ 2 ml Liter^{-1} water at 25 days interval	1.22 ab	1.14 ab	1.24 ab	13.22 b	14.33 bc	13.04 b
T_2 = Spraying Actara 25 WG @ 0.5 g Liter^{-1} water at 25 days interval	1.23 ab	1.14 ab	1.24 ab	13.68 b	14.83 b	13.50 b
T_3 = Spraying Voliam Flexi 300 SC @ 0.5ml Liter^{-1} water at 25 days interval	1.29 a	1.21 a	1.31 a	19.70 a	21.36 a	19.43 a
T_4 = IPM (Nappy+ Hand Weeding+ Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water apply when necessary)	1.19 b	1.11 b	1.21 b	10.21 c	11.07cd	10.07 c
T_5 = Ripcord 10 EC @ 1.0 ml Liter^{-1} water at 25 days interval	1.16 bc	1.07 bc	1.17 bc	7.20 d	7.81 d	7.10 d
T_6 = Untreated control	1.08 c	1.01 c	1.09 c	-	-	-
CV (%)	3.06	3.29	3.02	9.21	11.25	7.40

Data are the average of ten observations from 4 replications.
In a column, means followed by same letter(s) are not significantly different by Tukey's HSD test at *P<0.05*

4.4.4 Effect of different management practices against shoot and fruit borer on okra fruits in jhum field at Bandarban, Rangamati and Khagrachari from 2015 to 2016

Effect of different management practices against shoot and fruit borer on okra fruits varied statistically in the experimental fields at Bandarban, Rangamati and Khagrachari districts from 2015 to 2016. The results have been presented below:

4.4.4.1 Effect of different management practices against shoot and fruit borer on okra

Research results of 2015, results indicated considerable variation among the management practices in respect of the percent infested fruits plant^{-1} (Table 4.4.13).

The maximum percent of infestation were 30.47, 36.58 and 33.05 recorded from the untreated control from experimental jhum okra crop at Bandarban, Rangamati and Khagrachari respectively. Mean percentage of infested fruits plant^{-1} from untreated control were significantly at par with treatments T_4 (27.91) at Bandarban. However, it was not statistically different from T_4 (29.04) at Khagrachari.

Fruits damaged fluctuated were recorded from (19.95 to 30.47), (21.41 to 36.58) and (21.10 to 33.05) at Bandarban, Rangamati and Khagrachari respectively. At Bandarban, the lowest mean percentage of shoot and fruit borer infestation was recorded (19.95) from treatment T_3 which was statistically equivalent with treatments T_1 (22.72) and followed by T_2 (25.35).

Table 4.4.13 Effect of different management practices on okra fruits in jhum field applied against okra shoot and fruit borer infestation at Bandarban, Rangamati and Khagrachari during 2015

Treatments	Mean percentage infestation of fruits by okra shoot and fruit borer plant^{-1}			Percent reduction infestation of okra shoot and fruit borer plant^{-1}		
	Bandar -ban	Ranga -mati	Khagra -chari	Bandar -ban	Ranga -mati	Khagra -chari
T_1 = Farmers practice	22.72 cd	27.50 c	24.42 bc	25.46 b	24.83 b	33.25 b
T_2 = Spraying Actara 25 WG @ 0.5 g Liter^{-1} water at 25 days interval	25.35 bc	32.98 b	25.72 bc	16.82 c	9.83 c	29.68 b
T_3 = Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water at 25 days interval	19.95 d	21.41 d	21.10 c	34.54 a	41.46 a	42.32 a
T_4 = IPM (Nappy+ Hand Weeding+ Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water apply when necessary)	27.91 ab	31.72 b	29.04 ab	8.40 d	13.28 c	20.63 c
T_5 = Untreated control	30.47 a	36.58 a	33.05 a	-	-	-
CV (%)	**7.64**	**5.20**	**7.97**	**13.14**	**9.51**	**7.64**

Data are the average of ten observations from 4 replications.
In a column, means followed by same letter(s) are not significantly different by Tukey's HSD test at $P<0.05$

The lowest (21.41) percent of infestation was observed from treatment T_3 which was significantly different from all other treatments at Rangamati. Nevertheless, the second maximum percentage of infestation (27.50) was observed in T_1 treated plot which was significantly different from treatment T_4 (31.72) followed by treatment T_2 (32.98). However, at Khagrachari the lowest (21.10) percent of infestation was observed from treatment T_3 which was at par but numerically higher from treatments T_1 (24.42) and T_2 (25.72).

The reduction of total infested fruits plant^{-1} over control ranged from 8.40-34.54, 9.83-41.46 and 20.63-42.32 during the entire fruiting period indicating the habitual protection from okra fruit borer at

Bandarban, Rangamati and Khagrachari, correspondingly. The highest percent of reduction of infested fruit plant^{-1} over control was recorded from treatment T_3 (34.54) which was statistically unlike from all other treatments at Bandarban. The second peak percentage of reduction over control (25.46) was observed from treatment T_1 which was also significantly different from the treatment T_2 (16.82) followed by treatment T_4 (8.40). The highest percent of reduction of infestation over control was recorded from treatment T_3 (41.46) which was significantly different from all other treatments at Rangamati. The second uppermost rate of reduction over control (24.83) was observed from treatment T_1 which was significantly differed from the treatments T_4 (13.28) followed by treatment T_2 (9.83) which performed the lowest reduction at Rangamati. The highest percentage of reduction of infestation of infested fruit plant^{-1} over control was recorded from treatment T_3 (42.32) which significantly different from all other treatments but the next highest reduction was (33.25) from the treatment T_1 which did not significantly differed from the treatment T_2 (29.68) and followed by T_4 (20.63) at Khagrachari.

During the year 2016, the results indicated that large variation observed among the management practices in respect of the percent infested fruits plant^{-1} (Table 4.4.14). The maximum mean percent of infestation were 33.26, 36.58 and 33.05 recorded from the untreated control from experimental jhum okra crop at Bandarban, Rangamati and Khagrachari, respectively although the mean percent of infestation were statistically alike among the treatments T_2 (28.14 and 32.42) and T_4 (30.70 and 31.16) at Bandarban and Rangamati, respectively whereas, significantly different from all other treatments at Khagrachari.

At Bandarban, the lowest mean percentage of fruit fly infestation was recorded (22.73) from treatment T_3 which was statistically identical with treatments T_1 (25.50), T_5 (26.70) and T_2 (28.14) but unlike with treatment T_4 (30.70). The lowest (20.85) percent of infestation was observed from treatment T_3 which was at par with treatments T_5 (24.32) and significantly different from all other treatments. The second-lowest infestation was observed from treatment T_5 which was significantly similar with the treatment T_1 (26.93) followed by treatments T_4 (31.16) and T_2 (32.42) at Rangamati. Nevertheless, at Khagrachari the lowest (17.11) percent of infestation was observed from treatment T_3 which was at par but numerically to some extent higher infestation from the treatments T_1 (20.43), T_5 (20.55) followed by T_2 (21.74) and T_4 (25.05).

The reduction of percent infested fruits plant^{-1} over control was ranged from 7.70-31.65, 9.99-42.11 and 13.83-41.12 during the entire fruiting period indicating the projected protection from okra shoot and fruit borer at Bandarban, Rangamati and Khagrachari respectively. The highest percent of reduction of infested fruit plant^{-1} over control was achieved from treatment T_3 (31.65) which was statistically different from all other treatments at Bandarban.

Table 4.4.14 Effect of different management practices on okra fruits in jhum field applied against okra shoot and fruit borer infestation at Bandarban, Rangamati and Khagrachari during 2016

Treatments	Mean percentage infestation of fruits by okra shoot and fruit borer plant^{-1}			Percent reduction infestation of okra shoot and fruit borer plant^{-1}		
	Bandar-ban	Ranga-mati	Khagra-chari	Bandar-ban	Ranga-mati	Khagra-chari
T_1 = Spraying Marshal 20EC @ 2 ml Liter^{-1} water at 25 days interval	25.50 bc	26.93 bc	20.43 cd	23.32 b	25.22 c	29.71 b
T_2 = Spraying Actara 25WG @ 0.5 g Liter^{-1} water at 25 days interval	28.14 abc	32.42 a	21.74 bc	15.41c	9.99 d	25.22 b
T_3 = Spraying Voliam Flexi 300SC @ 0.5ml Liter^{-1} water at 25 days interval	22.73 c	20.85 d	17.11 d	31.65 a	42.11 a	41.12 a
T_4 = IPM (Nappy+ Hand Weeding+ Spraying Voliam Flexi 300SC @ 0.5 ml Liter^{-1} water apply when necessary)	30.70 ab	31.16 ab	25.05 b	7.70 d	13.49 d	13.83 c
T_5 = Ripcord 10EC @ 1.0 ml Liter^{-1} water at 25 days interval	26.70 bc	24.32 cd	20.55 cd	19.73 bc	32.47 b	29.30 b
T_6 = Untreated control	33.26 a	36.02 a	29.07 a	-	-	-
CV (%)	**9.79**	**7.83**	**7.80**	**13.03**	**9.77**	**13.09**

Data are the average of ten observations from 4 replications.
In a column, means followed by same letter(s) are not significantly different by Tukey's HSD test at $P<0.05$

The second-highest percent of reduction over control was (23.32) calculated from treatment T_1 which was significantly similar with the treatment T_5 (19.73) and was followed by treatments T_2 (15.41) and T_4 (7.70). Likewise, the highest percent of reduction of infestation over control was achieved from treatment T_3 (42.11) which was significantly different from all other treatments at Rangamati. Once more the second uppermost percentage of reduction over control (32.47) was observed from treatment T_5 which was significantly different with the treatments T_1 (25.22), T_4 (13.49) followed by treatment T_2 (9.99). The result indicated that the treatments had significant variation among them. The highest percent of reduction infested fruit plant^{-1}over control was recorded from treatment T_3 (41.12) which statistically different from all other treatments. However, the succeeding highest reduction was

(29.71) calculated from the treatment T_1 which was significantly at par with treatment T_5 (29.30) and T_2 (25.22) and was time followed by T_4 (13.83) at Khagrachari.

Results presented in Table 4.4.14 revealed that treatment T_3 comprising spray of voliam flexi 300 SC @ 0.5 ml liter^{-1} water at 25 days interval and T_2 using actara 25 WG @ 0.5 g liter^{-1} water at 25 days interval performed better than other treatments at all experimental fields of hill districts during both years. Other chemical treatments were failed to provide dependable results among the three hill district due to internal feeding behaviour and variation of rainfall might reduce their effectiveness to control fruit fly.

4.4.4.2 Effect of different management practices against aphid on okra

During the year 2015, results indicated that considerable variation in controlling aphid were observed among the management practices in respect of percent aphid infested leaves plant^{-1} (Table 4.4.15).

The maximum percent of infestation were 29.70, 31.83 and 34.08 documented from the untreated control from experimental jhum okra crop at Bandarban, Rangamati and Khagrachari, respectively also which were statistically different from all other treatments. At Bandarban, the lowest percent of aphid infested leaves plant^{-1} was recorded (15.38) from treatment T_3 which was statistically equivalent with treatments T_4, T_1 and T_2 (16.06, 16.92 and 18.42 respectively). Comparatively the lowest (16.42) percent of infestation was observed from treatment T_3 which was significantly different from all other treatments at Rangamati. However, the next uppermost percent reduction (22.80) over control was observed from treatment T_1 which was significantly identical with the treatments T_2 (24.73) and T4 (25.89). Conversely, at Khagrachari once again the lowest (12.56) mean percent of infestation was observed from treatment T_3 which was at par but numerically higher infestation from treatments T_2 (15.53) which was significantly different from treatments T_4 (18.97) and T_1 (19.57).

The reduction of the percent of infested leaves plant^{-1} over control ranged from (37.98-48.22), (18.02-48.002) and (18.02-63.14) during the entire fruiting period indicating the considerable protection from aphid at Bandarban, Rangamati and Khagrachari, correspondingly.

The highest percent of reduction of infestation over control was recorded from treatment T_3 (48.22) which was statistically identical with treatments T_4 and T_1 (42.57 and 42.79 respectively), followed T_2 (37.98) at Bandarban. Treatments T_4 performed the lowermost (18.02) reduction of infested leaves plant^{-1} over control and identical with treatment T_2 (21.68) but the topmost percent of reduction was recorded from treatment T_3 (48.002) with statistically different from all other treatments and the second-highest was in T_1 (27.79) at Rangamati.

Table 4.4.15 Effect of different management practices on okra leaves in jhum field applied against aphid infestation at Bandarban, Rangamati and Khagrachari during 2015

Treatments	Mean percentage aphid infested leaves plant^{-1}			Percent reduction infestation aphid infested leaves plant^{-1}		
	Bandar-ban	**Ranga-mati**	**Khagra-chari**	**Bandar-ban**	**Ranga-mati**	**Khagra-chari**
T_1 = Farmers practice	16.92 b	22.80 b	19.57 b	42.79 ab	27.79 b	42.575 c
T_2 = Spraying Actara 25 WG @ 0.5 g Liter^{-1} water at 25 days interval	18.42 b	24.73 b	15.53 c	37.98 b	21.68 c	54.42 b
T_3 = Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water at 25 days interval	15.38 b	16.42 c	12.56 c	48.22 a	48.02 a	63.14 a
T_4 = IPM (Nappy+ Hand Weeding+ Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water apply when necessary)	16.06 b	25.89 b	18.97 b	42.57 ab	18.02 c	44.33 c
T_5 = Untreated control	29.70 a	31.83 a	34.08 a	-	-	-
CV (%)	**9.42**	**6.44**	**6.85**	**7.21**	**6.50**	**7.65**

Data are the average of ten observations from 4 replications.
In a column, means followed by same letter(s) are not significantly different by Tukey's HSD test at $P<0.05$

The highest percent of reduction of infested leaves plant^{-1} over control was (63.14) recorded from treatment T_3 which was statistically different from all other treatments at Khagrachari. Again the second-highest percent of reduction over control (54.42) was observed in treatment T_2 which was significantly different from the treatments T_4 (44.33) followed by treatment T_1 (42.575). Among three hill districts, comparatively better reduction observed at Khagrachari was might be due to wash out of chemical by sudden rainfall after application on jhum crops.

During the year 2016, results indicated that considerable variation observed among the management practices in respect of percent infested aphid leaves plant^{-1} (Table 4.4.16). The highest mean percent infestation were 26.58, 28.10 and 29.09 recorded from the untreated control from experimental jhum okra crop at Bandarban, Rangamati and Khagrachari, respectively although the mean percent of infestation were statistically different from all other treatments at Bandarban, Rangamati and Khagrachari, correspondingly.

At Bandarban, the lowest mean percent of aphid infestation was recorded (12.26) from treatment T_3 which was statistically similar to T_1 and T_4 (13.80 and 13.94 respectively) and also followed by treatment T_2 (15.30). While Treatment T_5 (17.51) relatively less effective and significantly different from other treatments but statistically alike with T_2. Whereas, at Rangamati treatment T_5 accomplished minor infestation (19.58) which was statistically similar to treatment T_1 and followed by T_2 and T_4 (23.75 and 24.91 respectively). Among the treatments T_3 again showed the lowest (15.44) aphid infestation, and significantly different from all other treatments.

Table 4.4.16 Effect of different management practices on okra leaves in jhum field used against aphid infestation at Bandarban, Rangamati and Khagrachari during 2016

Treatments	Mean percentage aphid infested leaves plant^{-1}			Percent reduction infestation aphid infested leaves plant^{-1}		
	Bandar -ban	**Ranga -mati**	**Khagra -chari**	**Bandar -ban**	**Ranga -mati**	**Khagra -chari**
T_1 = Spraying Marshal 20 EC @ 2 ml Liter^{-1} water at 25 days interval	13.80 c	21.82 bc	14.58 b	48.09 b	28.68 c	49.88 c
T_2 = Spraying Actara 25 WG @ 0.5 g Liter^{-1} water at 25 days interval	15.30 bc	23.75 b	10.55 c	42.43 c	22.38 d	63.75 b
T_3 = Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water at 25 days interval	12.26 c	15.44 d	7.57 d	53.88 a	49.54 a	73.97 a
T_4 = IPM (Nappy+ Hand Weeding+ Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water apply when necessary)	13.94 c	24.91 b	13.98 b	47.57 bc	18.60 d	51.93 c
T_5 = Ripcord 10 EC @ 1.0 ml Liter^{-1} water at 25 days interval	17.51 b	19.58 c	15.54 b	34.14 d	36.02 b	46.59 c
T_6 = Untreated control	26.58 a	28.10 a	29.09 a	-	-	-
CV (%)	**8.65**	**6.10**	**7.25**	**5.13**	**7.26**	**7.31**

Data are the average of ten observations from 4 replications.
In a column, means followed by same letter(s) are not significantly different by Tukey’s HSD test at $P<0.05$

Among the treatments at Khagrachari, treatment T_5 (15.54) was less effective and significantly at par with the treatments T_4 and T_1 (13.98 and 14.58, separately) which were statistically different from all other treatments. The lowest (7.57) and second lowest (10.55) mean percent of infestation was observed from treatment T_3 and $T_{2,}$ respectively which were significantly different from other treatments.

The reduction of total infested leaves plant^{-1} over control ranged from (34.14-53.88), (18.60-49.54) and (46.59-73.97) during the entire fruiting period indicating the substantial protection from aphid at Bandarban, Rangamati and Khagrachari, correspondingly. The lowest percent of reduction of infestation of aphid leaves plant^{-1} over control was recorded from treatment T_5 (34.14) which was statistically differed from other treatments whereas treatment T_2 (42.43) performed comparatively better than T_5 which was at par with T_4 (42.57) and followed by T_1 (48.09). At Bandarban, the highest reduction of infestation over control was observed from treatment T_3 (53.88) which was statistically different from all other treatments. The highest percent of reduction of infested leaves plant^{-1} over control was recorded from treatment T_3 (49.54) which was significantly different from all other treatments at Rangamati. The next highest percent of reduction over control was (36.02) observed from treatment T_5 which was significantly varied with the treatments T_1, T_2 and T_4 (28.68, 22.38 and 18.60, respectively). Among the treatments at Rangamati wide range of reduction were evident but both T_2 and T_4 treatments achieved 22.38 and 18.60 reduction, respectively which were not substantialy as accomplished from other treatments.

The highest and the second highest reduction 73.97 and 63.75 were revealed from the treatments T_3 and $T_{2,}$ respectively besides and they were statistically different from other treatments at Khagrachari. However treatment T_4 (51.93) performed better at the experimental field of Khagrachari than Rangamati and Bandarban. They were significantly at par to that of treatments T_1 (49.88) and T_5 (46.59).

4.4.4.3 Effect of different management practices against jassid on okra

During the year 2015, results indicated considerable variation observed among the management practices in respect of percent of jassid infested leaves plant^{-1} (Table 4.4.17).

The maximum percent of infestation were 28.42, 35.74 and 31.54 recorded from the untreated control from experimental jhum okra crop at Bandarban, Rangamati and Khagrachari, respectively which were statistically unlike from all other treatments.

At Bandarban, the lowest mean percent of jassid infestation was recorded (14.20) from treatment T_3 which was statistically similar to treatments T_1, T_4 and T_2 15.68, 15.81 and 16.93, respectively. Comparatively the lowest (20.33) percent of infestation was observed from treatment T_3 which was significantly different from all other treatments at Rangamati. However, the second lowest infestation (26.72) was observed in T_1 treated plot which was significantly identical with the treatments T_2 (28.65) and T_4 (29.80).

At Khagrachari the lowest (10.03) percent of infestation was observed from treatment T_3 which was significantly different from other treatments. Nevertheless, the second lowermost of infestation (13.92) was observed from treatment T_2 which was significantly identical to that of the treatments T_4 (16.44) and T_1 (17.03).

The reduction of total infested leaves plant^{-1} over control were ranged from (40.44-50.04), (16.62-43.11) and (45.99-68.22) during the entire fruiting period indicating the sizeable protection from jassid at Bandarban, Rangamati and Khagrachari, correspondingly. The highest rate of reduction of infested leaves plant^{-1} over control was recorded from treatment T_3 (50.04) which was statistically indistinguishable with treatments T_1 (44.84) followed by treatments T_4 (44.36) and T_2 (40.44) at Bandarban. Treatments T_4 had the lowest (16.62) reduction of infested leaves plant^{-1} over control which was identical to treatment T_2 (19.85) but the uppermost percent of reduction was recorded from treatment T_3 (43.11) which was statistically different from all other treatments and was followed T_1 (25.25) at Rangamati.

Table 4.4.17 Effect of different management practices on okra leaves in jhum field treated against jassid infestation at Bandarban, Rangamati and Khagrachari during 2015

Treatments	Mean percentage jassid infested leaves plant^{-1}			Percent reduction infestation jassid infested leaves plant^{-1}		
	Bandar-ban	Ranga-mati	Khagra-chari	Bandar-ban	Ranga-mati	Khagra-chari
T_1 = Farmers practice	15.68 b	26.72 b	17.03 b	44.84 ab	25.25 b	45.99 c
T_2 = Spraying Actara 25 WG @ 0.5 g Liter^{-1} water at 25 days interval	16.93 b	28.65 b	13.92 b	40.44 b	19.85 c	55.88 b
T_3 = Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water at 25 days interval	14.20 b	20.33 c	10.03 c	50.04 a	43.11 a	68.22 a
T_4 = IPM (Nappy+ Hand Weeding+ Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water apply when necessary)	15.81 b	29.80 b	16.44 b	44.36 b	16.62 c	47.89 c
T_5= Untreated control	28.42 a	35.74 a	31.54 a	-	-	-
CV (%)	**11.57**	**6.53**	**7.95**	**5.57**	**6.31**	**4.19**

Data are the average of ten observations from 4 replications.
In a column, means followed by same letter(s) are not significantly different by Tukey's HSD test at $P<0.05$

The highest percentage of reduction of infested leaves plant^{-1} over control was recorded from treatment T_3 (68.22) which was significantly different from all other treatments at Khagrachari. Again the second uppermost rate of reduction over control (55.88) was observed from treatment T_2 which was significantly varied from treatments T_4 (47.89) followed by treatment T_1 (45.99). Among three hill districts, reasonably better reduction was observed at Khagrachari experimental jhum fields

During the year 2016, results showed a considerable variation observed among the management practices in respect of the percent of infested fruits plant^{-1} (Table 4.4.18). The highest mean percent of infestation were 18.51, 19.10 and 17.49 recorded from the untreated control from experimental jhum okra crop at Bandarban, Rangamati and Khagrachari, respectively although the mean percent of infestation were statistically different from all other treatments at Bandarban, Rangamati and Khagrachari, correspondingly.

Table 4.4.18 Effect of different management practices on okra leaves in jhum applied field against jassid infestation at Bandarban, Rangamati and Khagrachari during 2016

Treatments	Mean percentage aphid infested leaves plant^{-1}			Percent reduction infestation aphid infested leaves plant^{-1}		
	Bandar-ban	Ranga-mati	Khagra-chari	Bandar-ban	Ranga-mati	Khagra-chari
T_1 = Spraying Marshal 20 EC @ 2 ml Liter^{-1} water at 25 days interval	13.21 b	14.87 b	14.53 b	28.63 c	22.15 c	16.92 c
T_2 = Spraying Actara 25 WG @ 0.5 g Liter^{-1} water at 25 days interval	11.23 bc	12.75 bc	10.52 c	33.25 b	22.38 c	39.85 ab
T_3 = Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water at 25 days interval	10.12 c	9.44 d	10.45 c	45.33 a	50.58 a	46.03 a
T_4 = IPM (Nappy+ Hand Weeding+ Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water apply when necessary)	13.24 b	16.39 b	14.91 b	28.47 c	14.19 d	14.75 c
T_5 = Ripcord 10 EC @ 1.0 ml Liter^{-1} water at 25 days interval	14.11 b	13.18 bc	14.54 b	23.77 d	30.99 b	16.87 c
T_6 = Untreated control	18.51 a	19.10 a	17.49 a	-	-	-
CV (%)	**8.65**	**6.10**	**7.25**	**5.13**	**7.26**	**7.31**

Data are the average of ten observations from 4 replications.
In a column, means followed by same letter(s) are not significantly different by Tukey's HSD test at $P<0.05$

At Rangamati the lowest percent of aphid infestation was recorded (9.44) from treatment T_3 which was statistically different from all other treatments. The second lowermost infestation was (12.75) observed from treatment T_2 which was statistically identical with treatments T_5, T_1, and T_4 (13.18, 14.87 and 16.39, respectively) but different from untreated control. Whereas, at Bandarban and Khagrachari treatment T_3 achieved lower infestation (10.12 and 10.45) both were statistically similar with treatment T_2 and followed by T_1, T_5 and T_4, respectively. The untreated control had the highest percent of infestation and were significantly different from all other treatments.

The reduction of total infested leaves plant^{-1} over control ranged from (14.19 -50.58), (23.77 -45.33) and (14.75 -46.03) during the entire fruiting period indicating the substantial protection from aphid at Rangamati, Bandarban and Khagrachari, correspondingly. The lowest rate of reduction of infested fruit plant^{-1} over control was recorded from treatment T_4 (14.75) at Khagrachari which was statistically identical with treatments T_5 and T_1 whereas treatment T_2 (39.85) performed distant better than T_5 which was at par with T_3 (46.03). At Bandarban, the highest infestation reduction over control and was observed from treatment T_3 (45.33) which was statistically different from other treatments. The highest rate of reduction of infested leaves plant^{-1} over control was recorded from treatment T_3 (50.58) which was significantly different from all other treatments at Rangamati and followed by treatments T_2, T_5 and T_1 whereas T_4 performed least than the other chemical treatments at Rangamati. Again second-highest rate of reduction over control was (39.33) observed from treatment T_2 at Bandarban which was significantly varied with the treatments T_1, T_4 and T_5 (28.63, 28.47 and 23.77, respectively).

4.4.4.4 Effect of different management practices against whitefly on okra

Research result of 2015, indicated the considerable variation observed among the management practices in respect of the percent of whitefly infested leaves plant^{-1} (Table 4.4.19).

The maximum percent of infestation were (3.64, 3.33 and 3.95) recorded from the untreated control from the experimental field of jhum okra crop at Bandarban, Rangamati and Khagrachari, respectively which were statistically different from all other treatments.

At Bandarban the lowest percent of whitefly infestation was recorded (1.08) from treatment T_3 which was statistically different from all other treatments and followed by treatments T_4, T_1 and T_2 (1.44, 1.46 and 1.55, respectively) and these were statistically identical.

Comparatively the lowest (0.74) percent of infestation was observed from treatment T_3 which was significantly different from all other treatments at Rangamati. However, the second lowest percent of reduction was (1.06) observed from treatment T_2 which was significantly identical with the treatments T_1 followed T_4 (1.42). Conversely, at Khagrachari the lowest percent of infestation was (2.19) observed from treatment T_2 which was at par but numerically higher infestation from treatments T_3 and T_1 (2.27 and 2.33) and they were significantly different from treatments T_4.

The reduction of total infested leaves plant^{-1} over control ranged was from (57.45-70.33), (57.32-77.70) and (26.43-44.64) during the entire cropping period indicating a sizeable protection from whitefly at Bandarban, Rangamati and Khagrachari, congruently. The highest percent of reduction of infested leaves plant^{-1} over control was recorded from treatment T_3 (70.33 and 77.70) which was statistically different from other treatments at Bandarban and Rangamati, respectively. Whereas at Khagrachari the highest percent of reduction was (44.64) in treatment T_2 which was statistically similar with treatments T_3 and T_1 and followed by treatment T_4.

Table 4.4.19 Effect of different management practices on okra leaves in jhum field applied against whitefly infestation at Bandarban, Rangamati and Khagrachari during 2015

Treatments	Percentage okra whitefly infested leaves plant^{-1}			Percent reduction infestation of okra whitefly infested leaves plant^{-1}		
	Bandar-ban	**Ranga-mati**	**Khagra-chari**	**Bandar-ban**	**Ranga-mati**	**Khagra-chari**
T_1 = Farmers practice	1.46 b	1.13 c	2.33 c	62.89 b	68.95 b	41.02 a
T_2 = Spraying Actara 25 WG @ 0.5 m Liter^{-1} water at 25 days interval	1.55 b	1.06 c	2.19 c	57.45 b	68.29 b	44.64 a
T_3 = Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water at 25 days interval	1.08 c	0.74 d	2.27 c	70.33 a	77.70 a	42.60 a
T_4 = IPM (Nappy+ Hand Weeding+ Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water apply when necessary)	1.44 b	1.42 b	2.90 b	60.44 b	57.32 c	26.43 b
T_5 = Untreated control	3.64 a	3.33 a	3.95 a	-	-	-
CV (%)	**5.17**	**4.17**	**7.63**	**3.27**	**3.59**	**7.54**

Data are the average of ten observations from 4 replications.
In a column, means followed by same letter(s) are not significantly different by Tukey's HSD test at $P<0.05$

During the year 2016, results indicated that considerable variation observed among the management practices in respect of percent infested leaves plant^{-1} (Table 4.4.20). The highest percent of infestation were (2.55, 3.25 and 2.27) recorded from the untreated control from experimental jhum okra plant at Bandarban, Rangamati and Khagrachari, respectively even though the mean percentage of infestation were statistically different from all other treatments at Bandarban, Rangamati and Khagrachari, respectively. At Bandarban, the lowest percent of whitefly infestation was recorded (0.21) from treatment T_5 which was statistically different from all other treatments.

The second lowermost percent of whitefly infestation was revealed from treatments T_3 (0.36) which was identical to that of treatments T_1 and T_2 and followed by treatment T_4. Whereas, at Rangamati treatment T_3 achieved moderately lower infestation (0.66) which was statistically similar to treatment T_5 and followed by T_2 and T_1. Among the treatments at Khagrachari, treatment T_4 (1.23) was less effective and significantly different from all other treatments. Similar the lowest (0.51) mean percentage of infestation was observed from treatment T_2 which was significantly alike with treatments T_1 and T_3 and followed by treatment T_5.

Table 4.4.20 Effect of different management practices on okra leaves in jhum field treated against whitefly infestation at Bandarban, Rangamati and Khagrachari during 2016

Treatments	Mean percentage okra whitefly infested leaves plant^{-1}			Percent reduction infestation of okra whitefly infested leaves plant^{-1}		
	Bandar-ban	Ranga-mati	Khagra-chari	Bandar-ban	Ranga-mati	Khagra-chari
T_1 = Spraying Marshal 20 EC @ 2 ml Liter^{-1} water at 25 days interval	0.37 c	1.05 c	0.56 cd	85.49 ab	67.55 b	75.58 a
T_2 = Spraying Actara 25 WG @ 0.5 g Liter^{-1} water at 25 days interval	0.39 bc	0.98 c	0.51 d	85.71 ab	69.94 b	77.54 a
T_3 = Spraying Voliam Flexi 300 SC @ 0.5ml Liter^{-1} water at 25 days interval	0.36 c	0.66 d	0.59 cd	85.88 ab	79.58 a	73.99 a
T_4 = IPM (Nappy+ Hand Weeding+ Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water apply when necessary)	0.45 b	1.34 b	1.23 b	82.35 b	58.70 c	45.91 b
T_5 = Ripcord 10 EC @ 1.0 ml Liter^{-1} water at 25 days interval	0.21 d	0.87 cd	0.75 c	91.89 a	73.14 ab	67.22 a
T_6 = Untreated control	2.55 a	3.25 a	2.27 a	-	-	-
CV (%)	**4.53**	**9.06**	**9.72**	**4.93**	**5.42**	**6.98**

Data are the average of ten observations from 4 replications.
In a column, means followed by same letter(s) are not significantly different by Tukey's HSD test at *P<0.05*

The reduction of total infested leaves plant^{-1} over control ranged from (82.22-91.89), (58.70-79.58) and (45.91-77.54) during the entire cropping period indicating the substantial protection from whitefly at Bandarban, Rangamati and Khagrachari, correspondingly. The lowest percentage of reduction of infested leaves plant^{-1} over control was recorded from treatment T_4 (82.35) which was statistically at par with other treatments except for treatment T_5. At Bandarban, the highest infestation reduction over control was observed from treatment T_5 (91.89) which was statistically similar with treatments T_3, T_1 and T_2. The maximum rate of reduction of infested leaves plant^{-1} over control was recorded from treatment T_2 (77.54) which was significantly at par with all other treatments excluding IPM package *i.e.*, treatment T_4 at Khagrachari. Generally, all other treatment performed better than IPM package due to leaf infestation by whitefly was not significant enough to loss the crop economically thus the mentioned chemical was not applied to suppress the infestation as one component of IPM at all three hill district.

4.4.4.5 Effect of different management practices used against on okra fruit yield in jhum

During the 1st year (2015), yield result showed substantial divergence observed among the management practices in respect of okra fruit yield plant^{-1} (Table 4.4.21). Data uncovered that all the treated plots with different treatments were significantly higher than the untreated control plot during 2015 and 2016. Marketable okra fruit yield and percent yield increase over untreated control in different experimental plots of Bandarban, Rangamati and Khagrachari districts are presented in Table (4.4.21 and 4.4.22).

Table 4.4.21 Effect of different management practices used against on okra fruit yield in jhum field at Bandarban, Rangamati and Khagrachari during 2015

Treatments	Marketable okra fruit yield (g) plant^{-1}			Percent increase of yield over control		
	Bandar -ban	Ranga -mati	Khagra -chari	Bandar -ban	Ranga -mati	Khagra -chari
T_1 = Farmers practice	162.24 bc	157.87 bc	156.63 b	13.01 c	13.40 c	13.66 c
T_2 = Spraying Actara 25 WG @ 0.5 g Liter^{-1} water at 25 days interval	175.28 b	170.91 b	169.53 ab	22.08 b	22.78 b	23.02 b
T_3 = Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water at 25 days interval	200.99 a	196.62 a	195.21 a	39.99 a	41.25 a	41.66 a
T_4 = IPM (Nappy+ Hand Weeding+ Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water apply when necessary)	169.99 bc	162.62bc	159.21 b	18.40 bc	16.82 bc	15.54 bc
T_5 = Untreated control	143.57 c	139.21 c	137.80 b	-	-	-
CV (%)	5.75	6.66	9.54	8.28	8.38	9.07

Data are the average of ten observations from 4 replications.
In a column, means followed by same letter(s) are not significantly different by Tukey's HSD test at $P<0.05$

In jhum experimental fields during the first year (2015) confirmed that the highest yield (200.99 g plant^{-1} and 196.62 g plant^{-1}) were recorded from T_3 (spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1}

water at 25 days interval) at Bandarban and Rangamati, respectively, which were significantly different from all other treatments. Whereas at Khagrachari the highest fruit yield (195.21 g $plant^{-1}$) was recorded from the T_3 which was statistically identical with treatments T_2 (spraying Actara 25 WG @ 0.5 g $Liter^{-1}$ water at 25 days interval) but the statistically different from treatment T_1, T_4 and untreated control.

Untreated control plots at all experimental field of three hill districts produced the lowest yield due to comparatively higher fruit infestation. During the year 2015 different chemicals and IPM treatments percent of yield increase over untreated control were ranged from (13.01-41.66 kg $plant^{-1}$) which was a significant increase in the yield over untreated control. Though insect pests infestation comparatively lower at jhum fields than the hill valley. The order of effectiveness of four treatments over untreated control were $T_3 > T_2 > T_4 > T_1$.

During the second year (2016) results showed the extensive variation observed among the management practices in respect of okra fruit yield (Table 4.4.22). The result stated that marketable okra fruit yield at the experimental field of Bandarban was the highest (199.20 g $plant^{-1}$) recorded from treatment T_3 (spraying Voliam Flexi 300 SC @ 0.5 ml $Liter^{-1}$ water at 25 days interval), which was statistically different from all other treatments and was followed by treatments T_5, T_2, T_1 and T_4. However, treatment T_3 (spraying Voliam Flexi 300 SC @ 0.5ml $Liter^{-1}$ water at 25 days interval) again performed the best and provided the yield 197.16 g $plant^{-1}$ and 195.64 g $plant^{-1}$ at Khagrachari and Rangamati, respectively. Among the treatments at both hill districts T_3 showed statistically indistinguishable yield $plant^{-1}$ and were observed in the treatments of T_5 and T_2 and followed by treatments T_1 and T_4.

The lowest okra fruit yield (141.79, 139.75 and 138.22 kg $plant^{-1}$) was recorded from untreated treatment at Bandarban, Khagrachari and Rangamati, respectively and these were statistically different from treatment T_3 at all hill experimental jhum fields.

The major insect pest was okra shoot and fruit borer, aphid and jassid were intimidating pests of several crops specially Solanaceae crops. In the year 2016, different chemicals and IPM treatments the percent yield increase over untreated control were ranged from (11.58-41.54 kg $plant^{-1}$) which were satisfactory increase. The order of effectiveness of four treatments over untreated control were $T_3 > T_5 > T_2 > T_1 > T_4$. Jhumian people practice jhum cultivation during the monsoon period when the frequency of rainfall comparatively higher than other period. Jhumian people are not familiar with IPM practices thus all component were not efficiently used by them. Jhumian people do not spray insecticide in the selected IPM plot. The result revealed that treatment IPM (T_4) did not perform satisfactorily as compaired to other chemical treatments to suppress the insect pests for achieving yield increase over untreated control.

Table 4.4.22 Effect of different management practices used against on okra fruit yield in jhum field at Bandarban, Rangamati and Khagrachari during 2016

Treatments	Marketable okra fruit yield (g) plant^{-1}			Percent increase of yield over control		
	Bandar -ban	Ranga -mati	Khagra -chari	Bandar -ban	Ranga -mati	Khagra -chari
T_1 = Spraying Marshal 20 EC @ 2 ml Liter^{-1} water at 25 days interval	160.45 bc	156.89 b	158.57 bc	13.16 c	13.50 c	13.47 c
T_2 = Spraying Actara 25 WG @ 0.5 g Liter^{-1} water at 25 days interval	173.49 b	169.93 ab	171.47 ab	22.36 b	22.94 b	22.70 b
T_3 = Spraying Voliam Flexi 300 SC @ 0.5ml Liter^{-1} water at 25 days interval	199.20 a	195.64 a	197.16 a	40.50 a	41.54 a	41.08 a
T_4 = IPM (Nappy+ Hand Weeding+ Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water apply when necessary)	158.20 bc	154.64 b	156.16 bc	11.58 c	11.86 c	11.74 c
T_5 = Ripcord 10 EC @ 1.0 ml Liter^{-1} water at 25 days interval	174.07 b	170.50 ab	172.02 ab	22.77 b	20.85 b	23.10 b
T_6 = Untreated control	141.79 c	138.22 b	139.75 c	-	-	-
CV (%)	5.74	8.60	7.88	9.38	8.82	9.61

Data are the average of ten observations from 4 replications.
In a column, means followed by same letter(s) are not significantly different by Tukey's HSD test at $P<0.05$

4.4.5 Effect of different management practices applied against insect pests on a sesame

Effect of different management practices applied against insect pests attacking sesame and the yield of sesame seed varied significantly in the experimental fields at Bandarban, Rangamati and Khagrachari districts during 2015 to 2016. The results have been presented below:

4.4.5.1 Effect of different management practices against leaf webber caterpillar on sesame

During the year 2015, results indicated that considerable variation observed among the management practices in respect of the mean percent of leaf webber infested leaves plant^{-1} (Table 4.4.23).

The maximum mean percent of infestation were 8.85, 3.33 and 3.95 recorded from untreated control treatment from an experimental field of jhum sesame crop at Bandarban, Rangamati and Khagrachari, respectively and were statistically different from all other treatments. At Bandarban, the lowest mean percent of leaf webber caterpillar infestation was recorded (5.37) from treatment T_3 which was statistically different from all other treatments and followed by treatments T_2, T_4 and T_1 (6.89, 6.93 and 7.73) independently and these were statistically identical. The lowest (0.93) mean percent of infestation was observed from treatment T_3 which was significantly identical with that of treatment T_2 but statistically different from other treatments *i.e.*, T_4 and T_1 (2.50 and 2.74) at Rangamati. Conversely, at Khagrachari the lowest (5.85) percent of infestation was observed from treatment T_3 which was at par but numerically higher infestation from treatments T_2 and T_4 (5.88 and 6.21) but significant different from treatments T_1.

Table 4.4.23 Effect of different management practices on sesame leaves in jhum field applied against sesame leaf webber infestation at Bandarban, Rangamati and Khagrachari during 2015

Treatments	Mean percentage of sesame leaf webber infested leaves plant^{-1}			Percent reduction infestation of sesame leaf webber infested leaves plant^{-1}		
	Bandar-ban	Ranga-mati	Khagra-chari	Bandar-ban	Ranga-mati	Khagra-chari
T_1 = Farmers practice	7.73 b	2.74 b	7.33 b	12.62 c	50.11 b	54.88 b
T_2 = Spraying Actara 25 WG @ 0.5 g Liter^{-1} water at 25 days interval	6.89 b	1.50 c	5.88 c	22.08 b	72.67 a	63.80 a
T_3 = Spraying Voliam Flexi 300 SC @ 0.5ml Liter^{-1} water at 25 days interval	5.37 c	0.93 c	5.85 c	39.31 a	83.14 a	64.04 a
T_4 = IPM (Nappy+ Hand Weeding+ Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water apply when necessary)	6.93 b	2.50 b	6.21 c	15.62 bc	54.58 b	61.79 a
T_5 = Untreated control	8.85 a	5.50 a	16.25 a	-	-	-
CV (%)	**5.85**	**14.08**	**3.96**	**12.61**	**9.61**	**3.70**

Data are the average of ten observations from 4 replications.
In a column, means followed by same letter(s) are not significantly different by Tukey's HSD test at $P<0.05$

The reduction of total infested leaves plant^{-1} over control was ranged from (12.62-39.31), (50.11-83.14) and (54.88-64.04) during the entire cropping period indicating the considerable protection from aphid at Bandarban, Rangamati and Khagrachari, correspondingly. The highest rate of reduction of infested leaves per plant over control was recorded from treatment T_3 (39.31) which was statistically different from all other treatments at Bandarban. The second maximum reduction revealed from treatment T_2 (22.08) which was at par with treatment T_4 and was followed by T_1. The highest percent of reduction of infested leaves plant^{-1} over control was recorded from treatment T_3 (83.14) which was statistically at par with treatment T_2 but, significantly different from treatments T_4 and T_1 at Rangamati. However, at Khagrachari the highest rate of reduction over control was (64.04) revealed from treatment T_3 which was statistically similar to that of treatments T_2 and T_4 but different from T_1 (54.88).

During the year 2016, results indicated a considerable variation observed among the management practices in respect of the mean percent of infested leaf webber caterpillar on sesame (Table 4.4.24). The highest mean percent of infestation were (12.63, 11.28 and 18.60) recorded from untreated control from experimental jhum sesame crop at Bandarban, Rangamati and Khagrachari, respectively though they were statistically different from all treatments at Khagrachari. However untreated control was statistically identical with that of treatments (T_5 and T_4) at Bandarban and to treatment (T_5) at Rangamati.

Among the treatments at Khagrachari, treatment T_5 (13.53) was less effective and significantly different from other treatments. The lowermost mean percent of infestation was (8.19) recoded from treatment T_1 which was significantly alike with treatments T_2 and T_3 and followed by treatment T_4. At Bandarban, the lowest mean percent of leaf webber caterpillar infestation was recorded (9.15) from treatment T_3 which was statistically different from all other treatments and followed by treatments T_1, and T_2 (10.68 and 10.72), respectively and these were statistically identical. Whereas, at Rangamati, the treatment T_3 achieved rather lower infestation (6.71) which was statistically similar to that treatments T_1 and T_2 followed by treatment T_4.

The reduction of total infested leaves plant^{-1} over control ranged from (7.47-30.68), (4.53-40.53) and (27.27-55.75) during the cropping period indicating the substantial protection from leaf webber caterpillar at Bandarban, Rangamati and Khagrachari, correspondingly. The lowest percent of reduction of infestation of over control was recorded from treatment T_5 (4.53 and 27.27) which was statistically different from all other treatments at Rangamati and Khagrachari, respectively. The highest infestation reduction over control was observed from treatment T_3 (40.53) which was statistically similar to that of treatments T_1 and followed by treatments T_4 and T_2 at Rangamati. However, at Khagrachari the uppermost decrease was observed from treatment T_2 (55.75) which was statistically similar to that of treatments T_1 and T_3 and followed by T_4. At Bandarban, the maximum infestation reduction over control was observed from treatment T_5 (7.47) which was statistically similar to that of treatments T_4. The highest rate of reduction of infested leaves plant^{-1} over control was recorded from treatment T_3 (30.68) which was significantly different from all other treatments followed by treatments T_2 and T_1.

Table 4.4.24 Effect of different management practices on sesame leaves in jhum field used against sesame leaf webber infestation at Bandarban, Rangamati and Khagrachari during 2016

Treatments	Mean percentage of sesame leaf webber infested leaves plant^{-1}			Percent reduction infestation of sesame leaf webber infested leaves plant^{-1}		
	Bandar -ban	Ranga -mati	Khagra -chari	Bandar -ban	Ranga -mati	Khagra -chari
T_1 = Spraying Marshal 20 EC @ 2 ml Liter^{-1} water at 25 days interval	10.68 b	7.29 bc	8.19 d	18.82 b	35.43 a	55.71 a
T_2 = Spraying Actara 25WG @ 0.5 g Liter^{-1} water at 25 days interval	10.72 b	8.28 bc	8.23 d	19.13 b	26.61 b	55.75 a
T_3 = Spraying Voliam Flexi 300 SC @ 0.5ml Liter^{-1} water at 25 days interval	9.15 c	6.71 c	8.56 cd	30.68 a	40.53 a	53.99 a
T_4 = IPM (Nappy+ Hand Weeding+ Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water apply when necessary)	11.52 ab	8.53 b	9.68 c	12.80 c	24.43 b	47.96 b
T_5 = Ripcord 10 EC @ 1.0 ml Liter^{-1} water at 25 days interval	12.22 a	10.77 a	13.53 b	7.47 c	4.53 c	27.27 c
T_6 = Untreated control	12.63 a	11.28 a	18.60 a	-	-	-
CV (%)	**4.93**	**8.04**	**4.75**	**13.39**	**11.61**	**5.36**

Data are the average of ten observations from 4 replications.
In a column, means followed by same letter(s) are not significantly different by Tukey's HSD test at $P<0.05$

4.4.5.2 Effect of different management practices against pod borer on a sesame

In 2015, the results indicated a considerable variation observed among the management practices in respect of the mean percent of pod borer infested pods branch^{-1} plant^{-1} (Table 4.4.25).

The maximum mean percent of infestation were (2.16, 1.99 and 3.04) recorded from untreated control from the experimental jhum sesame crop at Bandarban, Rangamati and Khagrachari, respectively and they were statistically different from all other treatments. At Bandarban, the lowermost percent of pod borer infested pods branch^{-1} plant^{-1} was recorded (1.01) from treatment T_2 which was statistically alike to that of treatments T_3, and T_4 (1.18 and 1.21), respectively. The lowest (0.03) percent of infestation was observed from treatment T_2 which was significantly identical with treatment T_3 and different from others treatments, T_4 and T_1 (0.317and 1.21) at Rangamati. Conversely, at Khagrachari the lowest (1.20) percent of infestation was observed from treatment T_3 which was at par but numerically higher from treatment T_2 and they were significantly different from treatments T_4 and T_1. Among the treatments T_1 (farmer's practice) (2.47) performed to suppress pod borer infestation which was statistically identical to that of T_4.

The reduction of total infested pods branch^{-1} plant^{-1}over control was ranged from 13.02-53.24, 38.78-98.29 and 18.71-60.61 during the entire pod setting to pod maturing stage indicating the satisfactory protection from pod borer at Bandarban, Rangamati and Khagrachari, correspondingly.

The peak percent of reduction of infested pods branch^{-1} plant^{-1} over control was calculated from treatment T_2 (53.24) which was statistically different from all other treatments at Bandarban. The second maximum reduction recorded from treatment T_3 (45.31) which was at par with treatment T_4 and followed by T_1. The uppermost percent of reduction of infested pods branch^{-1} plant^{-1} over control was noted down from treatment T_2 (98.29) and they were statistically at par with treatments T_3 and T_4 whereas, significantly different from treatment T_1 at Rangamati. Whereas at Khagrachari the highest rate of reduction was (60.61) calculated from treatment T_3 which was statistically similar to that of treatment T_2 but statistically different from all other treatments.

Table 4.4.25 Effect of different management practices on sesame pod in jhum field applied against sesame pod borer infestation at Bandarban, Rangamati and Khagrachari during 2015

Treatments	Mean percentage of pod borer infested pod branch^{-1} plant^{-1}			Percent reduction infestation of sesame pod borer infested branch^{-1} plant^{-1}		
	Bandar-ban	Ranga-mati	Khagra-chari	Bandar-ban	Ranga-mati	Khagra-chari
T_1 = Farmers practice	1.87 b	1.21 b	2.47 b	13.02 c	38.78 b	18.71 c
T_2 = Spraying Actara 25 WG @ 0.5 g Liter^{-1} water at 25 days interval	1.01 c	0.03 d	1.42 c	53.24 a	98.29 a	53.38 a
T_3 = Spraying Voliam Flexi 300 SC @ 0.5ml Liter^{-1} water at 25 days interval	1.18 c	0.07 d	1.20 c	45.31 b	96.65 a	60.61 a
T_4 = IPM (Nappy+ Hand Weeding+ Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water apply when necessary)	1.21 c	0.317 c	2.14 b	43.80 b	84.04 a	29.60 b
T_5 = Untreated control	2.16 a	1.99 a	3.04 a	-	-	-
CV (%)	**7.37**	**13.92**	**8.86**	**8.32**	**11.06**	**10.73**

Data are the average of ten observations from 4 replications.
In a column, means followed by same letter(s) are not significantly different by Tukey's HSD test at $P<0.05$

In 2016, results indicated considerable variation observed among the management practices in respect of the percent of infested pods branch^{-1} plant^{-1} on sesame (Table 4.4.26). The maximum percent of infestation were (1.19, 2.09 and 2.14) recorded from untreated control from experimental jhum sesame crop at Bandarban, Rangamati and Khagrachari, respectively and they were statistically different from all other treatments at Rangamati and Khagrachari. Nevertheless, untreated control was statistically identical with treatment T_1 at Bandarban. Among the treatments at Bandarban, treatment T_1 (1.11) was less effective and significantly dissimilar from other treatments except for the untreated control (T_6). The lowest (0.07) percent of infestation was observed from treatment T_5 which was significantly different from all other treatments but the second lowermost pod borer infestation was (0.25) from treatment T_4 which was statistically identical to T_3 and followed by treatment T_2 (0.91).

At Rangamati the lowest percent of pod borer infestation was recorded (0.17) from treatment T_2 which was statistically similar to treatment T_3 and was statistically different from all other treatments. Among treatments, T_5 perform moderately to suppress infestation (0.46) and was significantly different from others in addition what followed T_4 and T_1. Whereas, at Khagrachari T_3 achieved the lowest infestation (0.30) which was statistically similar to that of treatments T_2 but statistically different from all other treatments. Again T_5 resulted reasonable lower infestation (1.17) which was statistically identical with T_2 and followed by treatment T_1.

The reduction of total infested pods branch^{-1} plant^{-1}over control ranged from (32.14-94.68), (36.14-92.16) and (26.54-85.96) during the entire pod setting to pod maturing stage indicating the substantial protection from pod borer caterpillar at Bandarban, Rangamati and Khagrachari, respectively.

The highest rate of reduction of infestation of pods branch^{-1} plant^{-1}over control was recorded from treatment T_5 (94.68) which was statistically different from all other treatments at Bandarban. The second highest infestation reduction over control was observed from treatment T_3 (82.22) which was statistically similar to that of treatments T_4 and followed by T_1 and T_2.

The lowest percent of reduction over control was recorded from treatment T_2 (92.16) which was statistically identical to that of treatments T_3 and T_5 at Rangamati and followed by T_4 and T_1. Among treatments, T_1 was less effective against pod borer to decrease (36.14) infestation over untreated control at Rangamati and statistically dissimilar from other treatments. However, at Khagrachari the highest reduction was observed from treatment T_3 (85.96) which was statistically parallel to that treatments T_2 but statistically unlike from others. The treatment (T_5) comprising with ripcord 10EC @ 1.0 ml liter^{-1} water at 25 days interval, moderately reduced infestation (45.23) which was at par with T_4 and statistically different from other treatments.

Table 4.4.26 Effect of different management practices on sesame pod in jhum field used against sesame pod borer infestation at Bandarban, Rangamati and Khagrachari during 2016

Treatments	Mean percentage of pod borer infested pod branch^{-1} plant^{-1}			Percent reduction infestation of sesame pod borer infested branch^{-1} plant^{-1}		
	Bandar-ban	Ranga-mati	Khagra-chari	Bandar-ban	Ranga-mati	Khagra-chari
T_1 = Spraying Marshal 20 EC @ 2 ml Liter^{-1} water at 25 days interval	1.11 a	1.26 b	1.58 b	32.14 c	36.14 c	26.54 c
T_2 = Spraying Actara 25 WG @ 0.5 g Liter^{-1} water at 25 days interval	0.91 b	0.17 e	0.52 d	33.86 c	92.16 a	75.71 a
T_3 = Spraying Voliam Flexi 300 SC @ 0.5ml Liter^{-1} water at 25 days interval	0.28 c	0.21 e	0.30 d	82.22 b	90.07 a	85.96 a
T_4 = IPM (Nappy+ Hand Weeding+ Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water apply when necessary)	0.25 c	0.93c	1.24 bc	79.85 b	56.22 b	41.97 b
T_5 = Ripcord 10 EC @ 1.0 ml Liter^{-1} water at 25 days interval	0.07 d	0.46 d	1.17 c	94.68 a	78.32 a	45.23 b
T_6 = Untreated control	1.19 a	2.09 a	2.14 a	-	-	-
CV (%)	**10.20**	**6.27**	**13.52**	**7.67**	**10.52**	**10.07**

Data are the average of ten observations from 4 replications.
In a column, means followed by same letter(s) are not significantly different by Tukey's HSD test at *P<0.05*

4.4.5.3 Effect of different management practices applied against different insect pests on sesame seed yield in jhum

In 2015, yield result showed a substantial deviation observed among the management practices in respect of sesame seed yield plant^{-1} (Table 4.4.27). Data uncovered that all the treated plots with different treatments seed yield plant^{-1} were significantly higher than the untreated control plot in both the year 2015 and 2016. Marketable sesame seed yield plant^{-1} and percent of yield increased over untreated control in different treatments at experimental plots of Bandarban, Rangamati and Khagrachari districts are presented in Table (4.4.27 and 4.4.28). In jhum experimental fields during the year 2015, and the highest yield (86.27 g plant^{-1}) was recorded from T_3 (spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water at 25 days interval) treated plot at Bandarban, which was significantly different from all other treatments except statistically at par to that of treatment T_2 (spraying Actara 25 WG @ 0.5 gm Liter^{-1} water at 25 days interval). The maximum seed yield were recorded from the same treatment T_3 at Khagrachari and Rangamati and statistically similar to that of treatments T_2. The third highest seed yield was obtained from the treatments T_4 *i.e.*, IPM (Nappy+ Hand Weeding+ Spraying Voliam Flexi 300 SC @ 0.5 ml $Liter^{-1}$ water apply when necessary) at all three experimental jhum fields in the hill districts of Bangladesh and followed by the treatments T_1 (Farmers practice) and T_5 untreated control which were statistically identical. Untreated control plots from at all experimental fields of three hill districts resulted the lowest seed yield due to presence of comparatively higher sucking insect mite and pests infestation thus pod formation comparatively lower than all the other treated plots.

During the year 2015, different chemicals and IPM treatments percentage of yield increase over untreated control were ranged from recorded 0.49-6.50 g $plant^{-1}$ was significantly higher yield over untreated control. The insect pests' infestation comparatively lower at jhum fields than the hill valley. The order of effectiveness of four treatments over untreated control were $T_3>T_2>T_4>T_1$.

Table 4.4.27 Effect of different management practices used against different insect pests' on sesame seed yield in jhum field at Bandarban, Rangamati and Khagrachari during 2015

Treatments	Marketable sesame seed yield (g) $plant^{-1}$			Percent increase of yield over control		
	Bandar-ban	Ranga-mati	Khagra-chari	Bandar-ban	Ranga-mati	Khagra-chari
T_1 = Farmers practice	82.27 bc	81.36 c	81.30 c	1.55 c	0.90 c	0.49 d
T_2 = Spraying Actara 25 WG @ 0.5 g $Liter^{-1}$ water at 25 days interval	85.30 ab	85.06 ab	85.19 ab	5.04 b	5.30 b	5.29 b
T_3 = Spraying Voliam Flexi 300 SC @ 0.5 ml $Liter^{-1}$ water at 25 days interval	86.27 a	86.03 a	86.15 a	6.48 a	6.50 a	6.49 a
T_4 = IPM (Nappy+ Hand Weeding+ Spraying Voliam Flexi 300 SC @ 0.5 ml $Liter^{-1}$ water apply when necessary)	82.32 bc	81.98 bc	82.11 bc	1.48 c	1.49 c	1.48 c
T_5 = Untreated control	81.01 c	80.77 c	80.90 c	-	-	-
CV (%)	1.86	1.71	1.74	10.65	8.21	11.95

Data are the average of ten observations from 4 replications.
In a column, means followed by same letter(s) are not significantly different by Tukey's HSD test at $P<0.05$

In the second year (2016) showed extensive variation among the management practices in respect of sesame seed yield (Table 4.4.28). The result stated that marketable sesame seed yield at the experimental field of Khagrachari was highest (88.45 g $plant^{-1}$) recorded from treatment T_3 (spraying Voliam Flexi 300 SC @ 0.5 ml $Liter^{-1}$ water at 25 days interval), which was statistically identical with all other treatments but different from untreated control. However, treatment T_3 again performed the best and provided highest yield (88.37 g plant^{-1} and 88.35 g plant^{-1}) at Bandarban and Rangamati, respectively and a similar trend was observed with other treatments except untreated control. Among the treatments numerically higher seed yield plant^{-1} (weight) were obtained from different treatments but they were statistically similar.

The lowest sesame seed yield of 82.62, 83.20 and 83.10 g plant^{-1} were obtained from untreated control plot at Bandarban, Khagrachari and Rangamati, respectively and these were statistically different from that of treatment T_3 at all hill experimental jhum fields but statistically identical with other treatments. The major insect and mite pest was sucking insect mite pest, whitefly, aphid and jassid were intimidating pests reduced the pod formation but pod borer infestation were very insignificant at all the experimental fields.

Table 4.4.28 Effect of different management practices used against different insect pests'on sesame seed yield in jhum field at Bandarban, Rangamati and Khagrachari during 2016

Treatments	Marketable sesame seed yield (g) plant^{-1}			Percent increase of yield over control		
	Bandar -ban	Ranga -mati	Khagra -chari	Bandar -ban	Ranga -mati	Khagr a -chari
T_1 = Spraying Marshal 20 EC @ 2 ml Liter^{-1} water at 25 days interval	86.63 ab	86.60 ab	86.71 ab	4.21 c	4.22 c	4.21 c
T_2 = Spraying Actara 25 WG @ 0.5 g Liter^{-1} water at 25 days interval	87.41 ab	87.38 ab	87.49 ab	5.15 b	5.15 b	5.15 b
T_3 = Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water at 25 days interval	88.37 a	88.35 a	88.45 a	6.32 a	6.32 a	6.31 a
T_4 = IPM (Nappy+ Hand Weeding+ Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water apply when necessary)	84.32 ab	84.30 ab	84.41 ab	1.45 e	1.45 e	1.44 e
T_5 = Ripcord 10 EC @ 1.0 ml Liter^{-1} water at 25 days interval	85.84 ab	85.81 ab	85.92 ab	3.26 d	3.31 d	3.26 d
T_6 = Untreated control	82.62 b	83.10 b	83.20 b	-	-	-
CV (%)	2.50	2.47	2.33	7.91	7.97	8.00

Data are the average of ten observations from 4 replications.
In a column, means followed by same letter(s) are not significantly different by Tukey's HSD test at $P<0.05$

In 2016 different chemicals and IPM treatments provided percent of yield increase over untreated control were ranged from recorded 1.44-6.32 g plant^{-1}. The order of effectiveness of four treatments over untreated control were $T_3>T_2>T_1>T_5>T_4$ indicated that the chemical treatments at the mature stage of sesame plant performed better than the farmer's practice. Jhumian people practice jhum cultivation during the monsoon period when the frequency of rainfall comparatively higher than other times. Jhumian people are not familiar with IPM practice thus all component were not efficiently used by them due to lower infestation by major insect & mites than the hilly valley. Jhumian people not spray insecticide in the selected IPM plot. The result revealed that treatment IPM (T_4) fail to perform a satisfactorily compaied to other chemical treatments to suppress the insect pests to provide yield increase over untreated control.

4.4.6 Effect of different management practices applied against rice insect pests on rice and their yield in jhum field at Bandarban, Rangamati and Khagrachari during 2015 to 2016

Effect of different management practices applied against rice insect pests on rice and their yield varied significantly in the experimental fields at Bandarban, Rangamati and Khagrachari districts during 2015 to 2016. The results have been presented below:

4.4.6.1 Effect of different management practices applied against rice bug

In 2015, results indicated that considerable variation were observed among the management practices in respect of the percent of grain infested panicle^{-1} plant^{-1} (Table 4.4.29).Grain damage were ranged from (2.71-9.34), (1.71-8.34) and (0.47-7.11) after panicle initiation to before harvesting of rice crop at Bandarban, Rangamati and Khagrachari respectively. The highest percent of damage were recorded from the untreated control plot which were significantly different from all other treatments at all three hill districts except treatments T_1 (8.47 and 6.23) at Bandarban and Khagrachari, respectively and treatment T_4 (7.63) at Bandarban. Treatment T_3 performed the best among the other treatment and the lowest mean grain infestation was (2.71) noted which significantly different from all other treatments except treatment T_2 (4.02) at Bandarban. However, at Rangamati the lowest percent of grain infestation was (1.71) recorded from treatment T_3 which was statistically different from all other treatments and followed by Treatments T_2 (3.02) T_4 (6.62) and T_1 (7.46). Similarly to the lowest (0.47) percent of infestation was observed from treatment T_3 which was significantly different from all other treatments and followed by treatments T_2 (1.78) and T_4 (5.39) at Khagrachari. Again during the year 2015, the reduction of the percent of grain infested panicle^{-1} plant^{-1} over control ranged from (9.34-70.97), (10.50-79.54) and (12.32-93.36) after panicle initiation till before harvesting of rice crop indicating the substantial protection from rice bug at Bandarban, Rangamati and Khagrachari correspondingly.

The highest rate of reduction of infested grain plant^{-1} over control was recorded from treatment T_3 (70.97, 79.54 and 93.36) at Bandarban, Rangamati and Khagrachari, correspondingly and these were statistically different from all other treatments of the experimental fields of three hill districts and followed by treatments T_2 (56.93, 63.86 and 74.94), T_4 (18.33, 20.58 and 24.16). Among the treatments farmers practice (T_1) contributed less reduction and were 9.34, 10.50 and 12.32 recorded against rice bug infestation over control at all experimental fields of three hill districts these were statistically different from all other treatments. Results indicated that Jhumian people could adopt some effective treatments instead of their own cultural practices.

Table 4.4.29 Effect of different management practices on rice panicle jhum field used against rice bug infestation at Bandarban, Rangamati and Khagrachari during 2015

Treatments	Mean percentage of grain infested panicle^{-1} plant^{-1}			Percent reduction infestation of grain infested panicle^{-1} plant^{-1}		
	Bandar-ban	Ranga-mati	Khagra-chari	Bandar-ban	Ranga-mati	Khagra-chari
T_1 = Farmers practice	8.47 a	7.46 b	6.23 ab	9.34 d	10.50 d	12.32 d
T_2 = Spraying Actara 25 WG @ 0.5 g Liter^{-1} water at 25 days interval	4.02 b	3.02 d	1.78 c	56.93 b	63.86 b	74.94 b
T_3 = Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water at 25 days interval	2.71 b	1.71 e	0.47 d	70.97 a	79.54 a	93.36 a
T_4 = IPM (Nappy+ Hand Weeding+ Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water apply when necessary)	7.63 a	6.62 c	5.39 b	18.33 c	20.58 c	24.16 c
T_5 = Untreated control	9.34 a	8.34 a	7.11 a	-		-
CV (%)	**11.88**	**5.37**	**9.42**	**5.56**	**9.65**	**3.97**

Data are the average of ten observations from 4 replications.
In a column, means followed by same letter(s) are not significantly different by Tukey's HSD test at *P<0.05*

In 2016, the results indicated considerable variation observed among the management practices in respect of the percent of grain infested panicle^{-1} plant^{-1} (Table 4.4.30). Grain damage were range were from (2.68-4.05), (0.93-2.51) and (1.08-4.15) after panicle initiation till before harvesting of rice crop at Bandarban, Rangamati and Khagrachari, respectively. The maximum percent of damage were verified from the untreated control which were significantly dissimilar from all other treatments at all three hill districts. Treatment T_5 performed best among the other treatments and the lowermost mean grain infestation was (2.60) noted which statistically significantly at par with the treatments T_2, T_1, T_3, and T_4 (2.68, 2.80, 2.85 and 3.23), respectively at Bandarban.

At Rangamati the lowest percent of grain infestation was recorded (0.93) from treatment T_3 which was statistically different from all other treatments and followed by Treatments T_1, T_5, T_4, and T_2 (1.41, 1.57, 1.60 and 1.64) respectively, however, these were statistically at par with each other. Similarly the lowest (1.08) percent of infestation was observed from treatment T_3 which was significantly different from all other treatments except T_2 and T_1 (1.18 and 1.53), respectively whereas reasonably higher infestation was (2.83) recorded from treatment T_4 which was statistically identical with treatments T_5 and T_1 at Khagrachari.

Table 4.4.30 Effect of different management practices on rice panicle in jhum field treated against rice bug infestation at Bandarban, Rangamati and Khagrachari during 2016

Treatments	Mean percentage rice bug infested panicle $hill^{-1}$			Percent reduction infestation of rice bug panicle $hill^{-1}$		
	Bandar -ban	Ranga -mati	Khagra -chari	Bandar -ban	Ranga -mati	Khagra -chari
T_1 = Spraying Marshal 20 EC @ 2 ml $Liter^{-1}$ water at 25 days interval	2.80 b	1.41 b	1.53 bc	30.37 a	43.88 b	63.13 b
T_2 = Spraying Actara 25 WG @ 0.5 g $Liter^{-1}$ water at 25 days interval	2.68 b	1.64 b	1.18 c	33.45 a	34.54 b	71.77 a
T_3 = Spraying Voliam Flexi 300 SC @ 0.5ml $Liter^{-1}$ water at 25 days interval	2.85 b	0.93 c	1.08 c	29.62 a	62.80 a	73.98 a
T_4 = IPM (Nappy+ Hand Weeding+ Spraying Voliam Flexi 300 SC @ 0.5 ml $Liter^{-1}$ water apply when necessary)	3.23 b	1.60 b	2.83 b	20.25 b	36.15 b	26.99 d
T_5 = Ripcord 10 EC @ 1.0 ml $Liter^{-1}$ water at 25 days interval	2.60 b	1.57 b	2.10 b	33.65 a	37.46 b	49.40 c
T_6 = Untreated control	4.05 a	2.51 a	4.15 a	-	-	-
CV (%)	**9.91**	**7.80**	**9.91**	**4.96**	**11.02**	**6.68**

Data are the average of ten observations from 4 replications.
In a column, means followed by same letter(s) are not significantly different by Tukey's HSD test at *P<0.05*

The reduction of the percent of infested grain $panicle^{-1}$ $plant^{-1}$ over control were ranged from (20.25-33.65), (36.15-62.80) and (26.99-73.98) after panicle initiation till before harvesting of rice crop indicating the substantial protection from rice bug at Bandarban, Rangamati and Khagrachari, respectively. The highest rate of reduction of infested grain $plant^{-1}$ over control was recorded from treatment T_5 (33.65) at Bandarban which was significantly at par with treatments T_2, T_1 and T_3 but unalike with treatment T_4 *i.e.*, IPM comprising nappy+ hand weeding+ spraying voliam flexi 300 SC @ 0.5 ml $liter^{-1}$ water apply when necessary was less effective to reduce only 20.25 bug infestation over control. At Rangamati the maximum reduction was 62.80 recorded from treatment T_3 which was significantly different from all other treatments. The second highest reduction was 43.88 observed from treatment T_1 which was statistically similar to that of the treatment T_5, T_4 and T_2.

The highest rate of reduction of infestation of infested grain $plant^{-1}$ over control was recorded from treatment T_3 (73.98) at Khagrachari which was significantly at par with treatments T_2. The third maximum reduction was (63.13) observed from treatment T_1 which was significantly different from T_5 and T_4. Among the treatments T_4 *i.e.,* IPM provided fewer reduction percent of grain infested panicle^{-1} plant^{-1} over control at all experimental fields of three hill districts. Jhumian people were not familiar with the use of IPM component.

4.4.6.2 Effect of different management practices applied against rice stem borer in jhum rice

In 2015, results indicated considerable variation observed among the management practices in respect of percent of rice stem borer infested stems hill^{-1} (Table 4.4.31). Stem damage were ranged from (0.16-1.30), (0.17-1.32) and (0.11-1.26) before panicle initiation till harvesting of rice crop at Bandarban, Rangamati and Khagrachari, respectively. The highest mean percent of damaged was recorded from untreated control which was significantly unlike from all other treatments at three hill districts except treatments T_1 (1.24 and 1.09) at Bandarban and Khagrachari, respectively. Treatment T_3 performed preeminent among the other treatments and the bottom most mean stem borer infestation was (0.16) noted which significantly difference from all other treatments except treatment T_2 (0.27) at Bandarban and followed by treatments T_4 (0.90). At Rangamati similar observation was (0.17) recorded from treatment T_3 which was statistically at par with T_2 (0.28) and they together were significantly different from all other treatments and followed by treatments T_4 (0.90) and T_1 (1.11). Parallelly the lowermost mean percentage of infestation was (0.11) observed in treatment T_3 which was significantly comparable with T_2 but different from all other treatments and followed by treatments T_4 (0.86) and T_1 (1.09) at Khagrachari.

The reduction of the percentage of infested rice stem borer infested stems hill^{-1} over control ranged from (4.46-80.82), (16.01-86.83) and (13.30-90.96) after rice plant arises till before harvesting of rice crop indicating the considerable protection from rice stem borer at Bandarban, Rangamati and Khagrachari, correspondingly. The highest rate of reduction of infested stem borer infested stems hill^{-1} over control was veried from treatment T_3 (80.82, 86.83 and 90.96) at Bandarban, Rangamati and Khagrachari on the contrary, those were statistically different from all other treatments except at par with treatment T_2 (82.17 and 79.03) at Khagrachari and Bandarban, respectively and followed by treatments T_2 (78.44) at Rangamati also T_4 (37.05, 30.58 and 32.03) at Bandarban, Rangamati and Khagrachari, respectively. Among the treatments farmers practice *i.e.*, T_1 achieved 4.46, 16.01 and 13.30 recorded against rice stem borer infestation over control at all experimental fields of three hill districts and they were statistically different from all other treatments. Results showed that Jhumian people might adopt some active treatments instead of their own ethnic practices.

Table 4.4.31 Effect of different management practices on rice stem in jhum field applied against rice stem borer infested stem hill^{-1} infestation at Bandarban, Rangamati and Khagrachari during 2015

Treatments	Mean number of rice stem borer infested stem hill^{-1}			Percent reduction infestation of rice stem borer infested stem hill^{-1}		
	Bandar-ban	Ranga-mati	Khagra-chari	Bandar-ban	Ranga-mati	Khagra-chari
T_1 = Farmers practice	1.24 a	1.11 b	1.09 a	4.46 c	16.01 d	13.30 c
T_2 = Spraying Actara 25 WG @ 0.5 g Liter^{-1} water at 25 days interval	0.27 c	0.28 d	0.22 c	79.03 a	78.44 b	82.17 a
T_3 = Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water at 25 days interval	0.16 c	0.17 d	0.11 c	80.82 a	86.83 a	90.96 a
T_4 = IPM (Nappy+ Hand Weeding+ Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water apply when necessary)	0.90 b	0.92 c	0.86 b	37.05 b	30.58 c	32.03 b
T_5 = Untreated control	1.30 a	1.32 a	1.26 a	-	-	-
CV (%)	**9.45**	**8.75**	**11.13**	**11.98**	**7.15**	**8.04**

Data are the average of ten observations from 4 replications.
In a column, means followed by same letter(s) are not significantly different by Tukey's HSD test at $P<0.05$

In 2016, the results indicated that considerable variation observed among the management practices in respect of percent damage of rice stem borer infested stems hill^{-1} (Table 4.4.32). Throughout the second year, stem borer damage were ranged from (1.52-2.97), (1.06-2.87) and (0.59-0.80) before panicle initiation till harvesting of rice crop at Bandarban, Rangamati and Khagrachari respectively. The highest percent of damage 2.97, 2.87 and 0.80 were recorded from the untreated control which were significantly different from all other treatments at all three hill districts.

Treatment T_3 performed the best among the treatments tested and the lowest percent stem borer infestation (1.52) was noted which significantly at par with the treatments T_1, T_2, T_4 and T_5, respectively at Bandarban. At Rangamati the lowest percent of grain infestation was recorded (1.06) from treatment T_2 which was statistically at par with treatments T_3, T_1, and T_5 and they alone followed by treatments T_4 (1.85). Similar the lowest percent of infestation was (0.59) observed from treatment T_3 which was not significantly different from all other treatments but T_2 (0.80). The second lowermost infestation were obtained from T_2 which was statistically identical with treatment T_1 and followed by treatments T_4 and T_5 at Khagrachari.

Table 4.4.32 Effect of different management practices on rice stems in jhum field applied against rice stem borer infestation at Bandarban, Rangamati and Khagrachari during 2016

Treatments	Mean percentage rice stem borer infested stems hill^{-1}			Percent reduction infestation rice stem borer stems hill^{-1}		
	Bandar-ban	Ranga-mati	Khagra-chari	Bandar-ban	Ranga-mati	Khagra-chari
T_1 = Spraying Marshal 20EC @ 2 ml Liter^{-1} water at 25 days interval	1.53 b	1.33 c	1.04 bc	48.58 a	53.55 a	66.66 bc
T_2 = Spraying Actara 25WG @ 0.5 g Liter^{-1} water at 25 days interval	1.56 b	1.06 c	0.80 cd	47.59 a	62.91 a	72.22 ab
T_3 = Spraying Voliam Flexi 300SC @ 0.5ml Liter^{-1} water at 25 days interval	1.52 b	1.10 c	0.59 d	48.72 a	61.75 a	79.43 a
T_4 = IPM (Nappy+ Hand Weeding+ Spraying Voliam Flexi 300SC @ 0.5 ml Liter^{-1} water apply when necessary)	1.63 b	1.85 b	1.09 b	44.99 a	35.38 b	62.46 c
T_5 = Ripcord 10EC @ 1.0 ml Liter^{-1} water at 25 days interval	1.72 b	1.39 bc	1.21 b	42.01 a	51.57 a	58.12 c
T_6 = Untreated control	2.97 a	2.87 a	2.89 a	-	-	-
CV (%)	**13.62**	**13.98**	**9.66**	**8.79**	**11.55**	**5.66**

Data are the average of ten observations from 4 replications.
In a column, means followed by same letter(s) are not significantly different by Tukey's HSD test at $P<0.05$

The reduction of infested stem hill^{-1} over control ranged from (42.01-48.72), (35.38-62.91) and (58.12-79.43) before panicle initiation till harvesting of rice crop indicating the considerable protection from rice stem borer at Bandarban, Rangamati and Khagrachari, correspondingly. The highest rate of reduction of infested stems hill^{-1} over control was recorded from treatment T_3 (33.65) at Bandarban which was statistically at par with treatments T_1, T_2, T_4 and T_5. At Rangamati the maximum reduction (62.80) was recorded from treatment T_2 which was significantly alike with treatments T_3, T_1, and T_5 but statistically different from treatment T_4 (35.38). The highest rate of reduction of infested stem hill^{-1} over control was documented from treatment T_3 (79.43) at Khagrachari which was statistically at par with treatments T_2, and different from other treatments. The second maximum reduction (72.22) was observed from treatment T_2 was also significantly at par with treatment T_1 and followed by T_4 and T_5 (62.46 and 58.12). Overall stem borer infestation was not adequate to damage the jhum rice economically but at intercrop experiment comparatively higher infestation were recorded from all experimental fields of hill districts.

4.4.6.3 Effect of different management practices applied against grasshoppers on jhum rice

In 2015, results indicated a considerable variation observed among the management practices in respect of percent grasshoppers infested leaves hill^{-1} (Table 4.4.33).

Table 4.4.33 Effect of different management practices on rice leaves jhum field treated against of grasshopper infestation at Bandarban, Rangamati and Khagrachari during 2015

Treatments	Mean number grasshopper infested leaves hill^{-1}			Percent reduction number grasshopper infested leaves hill^{-1}		
	Bandar-ban	Ranga-mati	Khagra-chari	Bandar-ban	Ranga-mati	Khagra-chari
T_1 = Farmers practice	15.49 ab	15.51 ab	10.12 a	1.62 c	11.43 b	6.91 c
T_2 = Spraying Actara 25 WG @ 0.5 g Liter^{-1} water at 25 days interval	6.19 c	7.96 c	1.32 c	59.23 a	54.56 a	87.87 a
T_3 = Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water at 25 days interval	5.52 c	7.28 c	1.14 c	64.23 a	58.42 a	89.50 a
T_4 = IPM (Nappy+ Hand Weeding+ Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water apply when necessary)	12.70 b	14.46 b	7.83 b	17.50 b	17.41 b	28.03 b
T_5 = Untreated control	15.75 a	17.51 a	10.87 a	-	-	-
CV (%)	11.19	7.28	9.07	7.63	10.29	10.75

Data are the average of ten observations from 4 replications.
In a column, means followed by same letter(s) are not significantly different by Tukey's HSD test at $P<0.05$

Leaves damaged were ranged from (5.52-15.75), (7.25-17.51) and (0.11-1.26) after rice plant arises till before harvesting of rice at Bandarban, Rangamati and Khagrachari, respectively. The highest percent of leaves damage were recorded from the untreated control plot which were significantly different from all other treatments at all three hill districts except treatments T_1 *i.e.*, farmers practice. Treatment T_3 performed outstanding and the lowest leaf infestation was (5.52, 7.28 and 1.14) recorded and they were which significantly different from all other treatments except treatment T_2 (0.27) at Bandarban, Rangamati and Khagrachari, correspondingly followed by T_4 (7.83) at Khagrachari also T_4 (12.70, 14.46) and T_1 (15.49, 15.51) at Bandarban and Rangamati, respectively. The percent reduction of grasshoppers infested leave hill^{-1} over control was ranged from (1.62-64.23), (11.43-58.42) and (6.91-89.50) after rice plant arises till before harvesting of rice crop at Bandarban, Rangamati and Khagrachari, correspondingly. The uppermost percent reduction of grasshoppers infested leaves hill^{-1} over control was recorded from treatment T_3 (64.23, 58.42 and 89.50) at Bandarban, Rangamati and Khagrachari, respectively and these were statistically different from all other treatments except at par with treatments T_2 (47.59, 62.91 and 72.22). Treatment T_4 *i.e.*, IPM include nappy+ hand weeding+ spraying voliam flexi 300 SC @ 0.5 ml liter^{-1} water apply when necessary failed to achieve satisfactory reduction and provided only 17.50, 17.41 and 28.03 of grasshoppers infested leaves hill^{-1} over control at Bandarban, Rangamati and Khagrachari, respectively but they were statistically at par with treatment T_1 (11.43) at Rangamati.

However among the treatments T_1 *i.e.*, farmers practice resulted mimimum reduction of percent leave infestation over control it indicated that Jhumian people need one or more sustainable method to replace their age old practices. In 2016, the leaves damage were ranged from (3.38-9.63), (0.69-2.99) and (0.62-2.61) after rice plant arises till before harvest of rice crop at Bandarban, Rangamati and Khagrachari, respectively (Table 4.4.34**).**

Table 4.4.34 Effect of different management practices on rice leaves in jhum field treated against rice grasshopper infestation at Bandarban, Rangamati and Khagrachari during 2016

Treatments	Mean percentage rice grasshopper infested leaves hill^{-1}			Percent reduction infestation of rice grasshopper leaves hill^{-1}		
	Bandar-ban	Ranga-mati	Khagra-chari	Bandar-ban	Ranga-mati	Khagra-chari
T_1 = Spraying Marshal 20 EC @ 2 ml Liter^{-1} water at 25 days interval	4.23 cd	0.83 c	0.78 c	56.11 b	72.32 ab	70.02 ab
T_2 = Spraying Actara 25 WG @ 0.5 g Liter^{-1} water at 25 days interval	5.14 bc	0.97 c	0.94 bc	46.65 c	67.60 ab	63.94 bc
T_3 = Spraying Voliam Flexi 300 SC @ 0.5ml Liter^{-1} water at 25 days interval	3.38 d	0.69 c	0.62 c	64.87 a	76.85 a	76.25 a
T_4 = IPM (Nappy+ Hand Weeding+ Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water apply when necessary)	6.14 b	1.13 c	1.13 b	36.22 d	62.32 b	56.60 c
T_5 = Ripcord 10 EC @ 1.0 ml Liter^{-1} water at 25 days interval	6.79 b	2.31 b	2.37 a	29.47 d	22.66 c	9.29 d
T_6 = Untreated control	9.63 a	2.99 a	2.61 a	-	-	-
CV (%)	**12.60**	**12.98**	**10.02**	**6.97**	**10.32**	**8.21**

Data are the average of ten observations from 4 replications.
In a column, means followed by same letter(s) are not significantly different by Tukey's HSD test at $P<0.05$

The highest percent damage were 9.63, 2.99 and 2.61 were recorded from the untreated control plot which were significantly different from all other treatments at all three hill districts except treatment T_5 at Khagrachari. Treatment T_3 performed the best among the treatments and resulted the lowermost mean leave infestation (3.38) which was significantly different from all other treatments excluding T_1 (4.23) at Bandarban.

The second lowest percent infestation was recorded from treatment T_1 which was significantly not different from T_2 (5.14) and followed by treatments T_4 and T_5. At Rangamati once again the lowest percent grasshoppers infested leave hill^{-1} was recorded (0.69) from the treatment T_3 which was statistically at par with T_1, T_2 and T_4 but dissimilar from the treatment T_5 (2.31). Whereas at Khagrachari the lowest percent of infestation was (0.62) observed from treatment T_3 which was not significantly different from T_1 and T_2 but statistically different from that of treatment T_4 (1.13). The reduction of the percent grasshoppers infested leave hill^{-1} over control were ranged from (29.47-64.87), (22.66-76.85) and (9.29-76.25) after rice plant arises till before harvest of rice crop at Bandarban, Rangamati and Khagrachari, correspondingly.

The highest percent reduction of grasshoppers infested leaves hill^{-1} over control was recorded from treatment T_3 (64.87) at Bandarban which was significantly different from all other treatments. The second maximum reduction (56.11) was recorded from treatment T_1 which was statistically different from other treatments and followed by T_2 (46.65), T_4 and T_5. Among the treatments T_5 having ripcord 10EC @ 1.0 ml liter^{-1} water at 25 days interval achieved less reduction of infestation over control (29.47) and was statistically identical with treatment T_4. Whereas at Rangamati the highest reduction (76.85) was recorded from treatment T_3 which was significantly alike with treatments T_1 and T_2 but different from treatment T_4 and T_5. The second highest reduction of infestation over control (72.32) was recorded from treatment T_1 which was at par with treatments T_2, T_4 and T_5.

The highest percent reduction of infestation of grasshoppers infested leaves hill^{-1} over control was recorded from treatment T_3 (76.25) at Khagrachari which was significantly at par with treatments T_1, but different from other treatments. The second maximum reduction was (70.02) observed from treatment T_1 but significantly at par with treatment T_2 (63.94) and followed by treatment T_4 (56.60). The treatment comprising ripcord 10EC @ 1.0 ml liter^{-1} water at 25 days interval achieved the lowest percent of reduction (9.29) was recorded from T_5, the results of which directed that chemical (ripcord 10EC) was not provided the satisfactory outcomes. Frequent rainfall might diminish the efficacy of ripcord 10EC at all the experimental hill districts. During both years of field experiments at jhum grasshopper infestation was relatively higher in the previous year *i.e.*, 2015 than the year 2016.

4.4.6.4 Effect of different management practices treated against leaf folder on jhum rice

In 2015, the results indicated that considerable variation were observed among the management practices in respect of percent leaf folder infested leaves $hill^{-1}$ (Table 4.4.35).

Table 4.4.35 Effect of different management practices on rice leaves in jhum field treated against leaf folder $hill^{-1}$ infestation at Bandarban, Rangamati and Khagrachari during 2015

Treatments	Mean percentage rice leaf folder infested leaves $hill^{-1}$			Percent reduction infestation of rice leaf folder infested leaves $hill^{-1}$		
	Bandar-ban	Ranga-mati	Khagra-chari	Bandar-ban	Ranga-mati	Khagra-chari
T_1 = Farmers practice	0.27 b	0.26 b	0.52 b	16.50 c	20.53 c	11.63 c
T_2 = Spraying Actara 25 WG @ 0.5 g $Liter^{-1}$ water at 25 days interval	0.12 cd	0.11 cd	0.37 cd	56.11 b	65.99 ab	37.39 ab
T_3 = Spraying Voliam Flexi 300 SC @ 0.5ml $Liter^{-1}$ water at 25 days interval	0.07 d	0.06 d	0.31 d	78.07 a	81.30 a	46.06 a
T_4 = IPM (Nappy+ Hand Weeding+ Spraying Voliam Flexi 300 SC @ 0.5 ml $Liter^{-1}$ water apply when necessary)	0.16 c	0.16 c	0.41 c	49.72 b	52.58 b	29.79 b
T_5 = Untreated control	0.34 a	0.33 a	0.58 a	-	-	-
CV (%)	**13.03**	**13.49**	**5.69**	**8.71**	**14.90**	**14.90**

Data are the average of ten observations from 4 replications.
In a column, means followed by same letter(s) are not significantly different by Tukey's HSD test at $P<0.05$

Nevertheless, in the subsequent year the leaf folder infestation was scanty, leaves damage was ranged from (0.07-0.34), (0.06-0.33) and (0.31-0.58) after rice plants arise till before harvesting of rice crop at Bandarban, Rangamati and Khagrachari, respectively. The highest percent of damage were (0.34, 0.33 and 0.58) recorded from the untreated control which were significantly different from all other treatments at all three hill districts. Treatment T_3 performed outstanding and lowermost mean leaves infestation was (0.07) noted and this was significantly different from all other treatments except treatment T_2 (0.12) at Bandarban. The second lowermost percent infestation was (0.12) recorded from treatment T_2 which was statistically at par with treatment T_4 (0.16) and followed by T_1 (0.27). Again the treatment T_3 performed the best and the lowest mean leaves infestation was (0.06) noted and this was significantly different from all other treatments except treatment T_2 (0.11) at Rangamati.

The second lowest percent infestation was (0.11) recorded from treatment T_2 which was statistically at par with treatment T_4 (0.16) and followed by T_1 (0.26). Whereas at Khagrachari among the treatments again T_3 performed the best and the lowest mean leaves infestation was (0.31) noted and which were significantly different from all other treatments except treatment T_2 (0.37). Furthermore, treatment T_2 which showed the second lowest percent of infestation and significantly at par with T_4 (0.41) and followed by treatment T_1 (0.52). Among the treatment T_1 having farmers practice was failed to not to achieve satisfactory results all the three experimental fields' of hill districts.

The reduction percent over control leaf folder infested leaves hill^{-1} was ranged from (16.50-78.07), (20.53-81.30) and (11.63-46.06) after rice plant arises till before harvest of rice crop at Bandarban, Rangamati and Khagrachari correspondingly. The highest percent reduction of leaf folder infested leaves hill^{-1} over control was recorded from treatment T_3 (78.07, 81.30 and 46.06) at Bandarban, Rangamati and Khagrachari respectively and those were statistically different from all other treatments accept similar to that of treatments T_2 (65.99 and 37.39) at Rangamati and Khagrachari, respectively. Treatment T_4 *i.e.,* IPM comprising (nappy+ hand weeding+ spraying voliam flexi 300 SC @ 0.5 ml liter^{-1} water apply when necessary) achieve moderately decreased leaf folder infested leaves hill^{-1} over control and were (49.72, 52.58 and 29.79) which was also statistically at par with treatment T_2 at Bandarban, Rangamati and Khagrachari respectively and followed by treatment T_1. Among the treatments, farmers' practice (T_1) was failed to achieve satisfactory results not provided the lowest percent reduction of (16.50, 20.53 and 11.63) leaf folder infested leaves hill^{-1} over control and these was significantly different from all other treatments. Results pointed out that Jhumian people need sustainable method to replace their age old farmer's practices.

4.4.6.5 Effect of different management practices applied against flea beetle on jhum rice

In the 2016, results indicated that considerable variation among the management practices in respect of percent flea beetle-infested leaves hill^{-1} (Table 4.4.36). Leave damage were ranged from (10.69-19.80), (10.32-16.61) and (0.07-0.68) after rice plants arise till the maximum tillering stage of rice crop at Bandarban, Rangamati and Khagrachari, respectively. The highest percent damage were (19.80, 16.61and 0.68) recorded from the untreated control which were significantly different from all other treatments at all three hill districts except T_2 and T_2 (14.30 and 13.77) at Rangamati, respectively.

Treatment T_3 performed the best and lowest leave infestation was (10.69) noted which significantly at par from all other treatments except treatment T_4 (14.21) at Bandarban. The second lowest percent infestation was (12.96) recorded from treatment T_2 which statisticaly at par with treatment T_5 (13.45) and T_1 (13.48) followed by T_4. Again at Rangamati, the lowest mean percent flea beetle infestation was recorded (10.28) from treatment T_5 which was statistically similar with treatments T_3 (10.32) and T_1 (12.32) but statistically dissimilar from treatment T_4 and T_2. Among the treatments comparatively lower perform were recorded from treatments T_4 and T_2 (13.77 and 14.30) both were statistically identical with untreated control. Whereas at Khagrachari among the treatments the T_5 performed outstanding and the lowest leave infestation was (0.06) which was significantly different from all other treatments except treatment T_3 (0.07).

Table 4.4.36 Effect of different management practices on rice leaves jhum field applied against flea beetle infestation at Bandarban, Rangamati and Khagrachari during 2016

Treatments	Mean percentage flea beetle infested leaves hill^{-1}			Percent reduction infestation of flea beetle leaves hill^{-1}		
	Bandar -ban	Ranga -mati	Khagra -chari	Bandar -ban	Ranga -mati	Khagra -chari
T_1 = Spraying Marshal 20 EC @ 2 ml Liter^{-1} water at 25 days interval	13.48 bc	12.32 bc	0.21 c	31.96 bc	25.82 b	69.49 b
T_2 = Spraying Actara 25 WG @ 0.5 g Liter^{-1} water at 25 days interval	12.96 bc	14.30 ab	0.46 b	34.55 b	13.86 c	31.39 c
T_3 = Spraying Voliam Flexi 300 SC @ 0.5ml Liter^{-1} water at 25 days interval	10.69 c	10.32 c	0.07 d	46.05 a	37.87 a	90.09 a
T_4 = IPM (Nappy+ Hand Weeding+ Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water apply when necessary)	14.21 b	13.77 ab	0.24 c	28.24 c	17.06 c	64.49 b
T_5 = Ripcord 10 EC @ 1.0 ml Liter^{-1} water at 25 days interval	13.45 bc	10.28 c	0.06 d	32.07 bc	38.13 a	91.03 a
T_6 = Untreated control	19.80 a	16.61 a	0.68 a	-	-	-
CV (%)	8.88	10.02	11.82	6.29	11.93	4.88

Data are the average of ten observations from 4 replications.
In a column, means followed by same letter(s) are not significantly different by Tukey's HSD test at *P<0.05*

Furthermore, treatment T_1 (0.21) which provided was the third lowermost percent of infestation which was significantly at par with T_4 (0.24) and both were statistically different from all other treatments. Comparatively the higher leave infestation was 0.46 observed from treatment T_2 which was statistically different from other treatment and was followed by treatments T_4 and T_1 having 0.24

and 0.21, respectively. Flea beetle infestation at Khagrachari was scarce compared to Bandarban and Rangamati jhum experimental fields.

Results indicated that at the tillering stage of rice plant in both the experimental fields which were suddenly attacked by tiny flea beetle in the experimental field of 2016 but was not found in 2015. The reduction of percent of flea beetle-infested leaves hill^{-1} over control was ranged from (28.24-46.05), (13.86-38.13) and (31.39-91.03) after rice plant arises till maximum tillering of rice crop at Bandarban, Rangamati and Khagrachari, respectively.

The highest percent reduction of flea beetle-infested leaves hill^{-1} over control was recorded from treatment T_5 (91.03 and 38.13) and those were statistically at par with treatment T_3 (90.09 and 37.87) at Khagrachari and Rangamati, respectively but significantly different from all other treatments. Whereas at Bandarban T_3 performed the best to reduce the percent of infestation over control was 46.05 and significantly different from all other treatments. The second maximum reduction was 34.55 obtained from treatment T_2 which was statistically at par with the treatments T_5 and T_1 (32.07 and 31.96), correspondingly was recorded and followed by T_4 at Bandarban. At Khagrachari the third-highest reduction was 69.49 was recorded from the treatments T_1 which was identical with treatment T_4 (64.49) both were significantly different from all other treatments and was followed by treatment T_2. However, at Rangamati the lower percent of reduction was 13.86 obtained from treatment T_2 which was statistically at par with T_4 but statistically different from other treatments. Treatment T_1 achieved moderate reduction percent of flea beetle-infested leaves hill^{-1} over control and was statistically different from other treatments.

Flea beetle generally habituates to feed other leafy vegetables and decaying foliage on the soil. Results pointed out that both at Bandarban and Rangamati experimental jhum and intercrop rice leaves tip infested by tiny black flea beetle through scrapping chlorophyll content. This actively resulted a clear white streak as well as the appearance of unhealthy rice fields. Nonetheless, infestation confined during the initial tillering to a maximum tillering stage of rice.

4.4.6.6 Effect of different management practices applied against leafhoppers on jhum rice

In 2016, results indicated that considerable variation observed among the management practices in respect of the percent of damage by leafhoppers infested leaves hill^{-1} (Table 4.4.37). Nevertheless, in the previous year (2015) leafhoppers infestation was ample and was not reported here.

Leaves damage were ranged from (0.05-0.47), (0.12-0.48) and (0.09-0.68) after rice plants arise till to harvesting of rice crop at Bandarban, Rangamati and Khagrachari, respectively. The highest percent of damage were (0.47, 0.48 and 0.68) recorded from the untreated control which were significantly different from all other treatments at all three hill districts. At Bandarban the lowest percent of leafhoppers infestation was recorded (0.05) from treatment T_2 which was statistically alike with treatments T_3 and T_1 (0.08 and 0.09) respectively and followed by T_4 and T_5 (0.12 and 0.13). Again at Rangamati the lowest percent leafhopper infestation was recorded (0.12) from treatment T_3 which was statistically similar to that of treatments T_2 (0.14), T_1 (0.15) and T_5 (0.16) but statistically different from treatment T_4 (0.19).

Table 4.4.37 Effect of different management practices on rice leaves in jhum field treated against rice leafhopper infestation at Bandarban, Rangamati and Khagrachari during 2016

Treatments	Mean percentage rice green leafhopper infested leaves hill^{-1}			Percent reduction infestation of rice green leafhopper hill^{-1}		
	Bandar -ban	Ranga -mati	Khagra -chari	Bandar -ban	Ranga -mati	Khagra -chari
T_1 = Spraying Marshal 20 EC @ 2 ml Liter^{-1} water at 25 days interval	0.09 bc	0.15 bc	0.18 b	81.12 a	65.77 ab	55.24 b
T_2 = Spraying Actara 25 WG @ 0.5 g Liter^{-1} water at 25 days interval	0.05 c	0.14 c	0.12 cd	90.06 a	66.42 ab	71.67 a
T_3 = Spraying Voliam Flexi 300 SC @ 0.5ml Liter^{-1} water at 25 days interval	0.08 bc	0.12 c	0.09 d	83.49 a	71.55 a	77.06 a
T_4 = IPM (Nappy+ Hand Weeding+ Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water apply when necessary)	0.12 b	0.19 b	0.19 b	73.49 a	57.12 b	54.66 b
T_5 = Ripcord 10 EC @ 1.0 ml Liter^{-1} water at 25 days interval	0.13 b	0.16 bc	0.14 c	72.57 a	64.19 a	65.11 ab
T_5 = Untreated control	0.47 a	0.48 a	0.41 a	-	-	-
CV (%)	**14.99**	**9.12**	**8.59**	**9.66**	**6.58**	**11.15**

Data are the average of ten observations from 4 replications.
In a column, means followed by same letter(s) are not significantly different by Tukey's HSD test at $P<0.05$

Whereas at Khagrachari among the treatments T_3 performed outstanding and the lowest mean leaves infestation (0.09) was recorded and this was which significantly differs from all other treatments except treatment T_2 (0.12). Furthermore, treatment T_5 (0.14) was the third lowermost percent of infestation but significantly at per with T_2 (0.24). Comparatively higher mean leaves infestation was 0.19 observed from all treatment T_4 which was statistically identical with treatment T_1 (0.18) but statistically different from other treatments. Results indicated was that leafhopper infestation sporadic and scanty at all the experimental fields of hill districts during the experiment of 2016.

The reduction percent of leafhopper infested leaves hill^{-1} over control was ranged from (72.57-90.06), (57.12-71.55) and (54.66-77.06) after rice plant arises till harvesting of rice crop at Bandarban, Rangamati and Khagrachari, respectively. The highest percent reduction of leafhopper infested leaves hill^{-1} over control was recorded from treatment T_2 (90.06) and those were statistically at par with all other treatments T_3, T_1, T_4 and T_5 (83.49, 81.12, 73.49 and 72.57) at Bandarban, respectively. Whereas at Rangamati T_3 performed the best to reduce the percent infestation over control was 71.55 and it was significantly similar with treatments T_2, T_1 and T_5 but different from treatment T_4 (57.12). At Khagrachari once again percent reduction of leafhopper infested leaves hill^{-1} over control was recorded from treatment T_3 (77.06) similarly those were statistically at par with treatments T_2, and T_5 (71.67 and 65.11), respectively and was followed by T_1 and T_4 (55.24 and 54.66), respectively. Leafhopper infestation confined during the initial tillering to harvesting stage of rice at all experimental fields of hill districts. On the other hand rice crop did not shown any symptom of tungro virus thus indicated that both (green and redish) leafhoppers didn't transmit this virus.

4.4.6.7 Effect of different management practices used against stem borer on rice grain yield in jhum

In 2015 the yield result displayed a considerable deviation observed among the management practices in respect of rice grain yield ton ha^{-1} (Table 4.4.38).

Data uncovered that all the plots treated with different management practices resulted higher yield which were significantly higher than the untreated control during 2015 and 2016. Marketable rice grain yield ton ha^{-1}and percent of yield over untreated control in different treatments at experimental plots of Bandarban, Rangamati and Khagrachari districts were presented in Table (4.4.38 and 4.4.39). In jhum experimental fields during the 2015 confirmed that the highest yield (3.75 ton ha^{-1}) was recorded from T_3 (spraying Voliam Flexi 300 SC @ 0.5ml Liter^{-1} water at 25 days interval) treated plot at Khagrachari, which was significant different from all other treatments except at par with treatment T_2 (spraying Actara 25 WG @ 0.5 g Liter^{-1} water at 25 days interval) treated plot. Yield at Khagrachari experimental jhum field was comparatively higher due to lower flee beetle infestation during the tillering stage as well as higher stem borer and rice bug infestation observed in other experimental jhum fields of Bandarban and Rangamati. The maximum seed yield trend were 3.57 and 3.55 ton ha^{-1} recorded from the same treatment (T_3) at Bandarban and Rangamati and those were statistically similar to that of treatments T_2. The third highest seed yield (2.57, 2.58 and 2.44 ton ha^{-1}) were recorded from the IPM treatments T_4 (Nappy trap+ Hand Weeding+ Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water apply when necessary) at Khagrachari, Rangamati and Bandarban experimental jhum fields, respectively and was followed by the treatments T_1 (Farmers practice) and

T_5 (untreated control) but those were statistically identical. Untreated control plots at all experimental fields of three hill districts provided the lowest seed yield due to comparatively higher leaf feeding, stem borer and sucking insect pest's infestation.

Table 4.4.38 Effect of different management practices applied against stem borer on rice yield in jhum field at Bandarban, Rangamati and Khagrachari during 2015

Treatments	Marketable rice yield ton ha^{-1}			Percent increase of yield over control		
	Bandar -ban	Ranga -mati	Khagra -chari	Bandar -ban	Ranga -mati	Khagra -chari
T_1 = Farmers practice	1.94 c	2.07 c	2.13 bc	3.98 d	4.93 d	10.94 d
T_2 = Spraying Actara 25WG @ 0.5 g Liter^{-1} water at 25 days interval	3.22 a	3.22 a	3.26 a	72.35 b	62.86 b	69.44 b
T_3 = Spraying Voliam Flexi 30 0SC @ 0.5ml Liter^{-1} water at 25 days interval	3.57 a	3.55 a	3.75 a	90.66 a	79.68 a	94.87 a
T_4 = IPM (Nappy+ Hand Weeding+ Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water apply when necessary)	2.44 b	2.58 b	2.57 b	30.38 c	30.60 c	33.36 c
T_5 = Untreated control	1.92 c	2.01 c	1.92 c			
CV (%)	8.13	7.46	8.43	9.87	4.07	3.84

Data are the average of ten observations from 4 replications.
In a column, means followed by same letter(s) are not significantly different by Tukey's HSD test at $P<0.05$

In 2015 different chemicals and IPM treatments provided percent yield increase over untreated control and were recorded 3.98-94.87 which were also significantly higher over untreated control. Though insect pest's infestation comparatively lower at jhum fields than the hill valley, the order of effectiveness of four treatments over untreated control were $T_3>T_2>T_4>T_1\geq T_5$.

In the second year 2016 showed extensive variation among the management practices in respect of rice grain yield ton ha^{-1} (Table 4.4.39). The result stated that marketable rice grain yield ton ha^{-1} at the experimental field of Khagrachari was highest (3.81 ton ha^{-1}) and recorded from treatment T_3 (spraying Voliam Flexi 300 SC @ 0.5ml Liter^{-1} water at 25 days interval), which was statistically different from all other treatments.

The second highest grain yield was (3.34 ton ha^{-1}) received from the treatment T_5 (Ripcord 10 EC @ 1.0 ml Liter^{-1} water at 25 days interval) treated plot which was statistically identical with other chemical treatments but significantly different from treatment T_4 *i.e.*, IPM (Nappy+ Hand Weeding+ Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water apply when necessary) and untreated control.

Table 4.4.39 Effect of different management practices on rice yield in jhum field at Bandarban, Rangamati and Khagrachari during 2016

Treatments	Marketable rice yield of ton ha^{-1}			Percent increase of yield over control		
	Bandar -ban	Ranga -mati	Khagra -chari	Bandar -ban	Ranga -mati	Khagra -chari
T_1 = Spraying Marshal 20 EC @ 2 ml $Liter^{-1}$ water at 25 days interval	3.10 bc	2.92 bc	3.23 b	58.21 c	57.82 c	62.40 b
T_2 = Spraying Actara 25 WG @ 0.5 g $Liter^{-1}$ water at 25 days interval	3.31 ab	3.09 b	3.32 b	69.06 b	67.14 b	67.17 b
T_3 = Spraying Voliam Flexi 300 SC @ 0.5ml $Liter^{-1}$ water at 25 days interval	3.66 a	3.43 a	3.81 a	86.53 a	85.11 a	91.77 a
T_4 = IPM (Nappy+ Hand Weeding+ Spraying Voliam Flexi 300 SC @ 0.5 ml $Liter^{-1}$ water apply when necessary)	2.53 d	2.46 d	2.63 c	28.99 e	32.68 e	32.27 c
T_5 = Ripcord 10 EC @ 1.0 ml $Liter^{-1}$ water at 25 days interval	2.86 cd	2.73 cd	3.34 b	45.96 d	47.29 d	67.80 b
T_6 = Untreated control	1.96 e	1.80 e	1.99 d	-	-	-
CV (%)	5.90	5.11	5.81	7.17	3.66	4.80

Data are the average of ten observations from 4 replications.
In a column, means followed by same letter(s) are not significantly different by Tukey's HSD test at $P<0.05$

However, treatment T_3 (spraying Voliam Flexi 300 SC @ 0.5ml $Liter^{-1}$ water at 25 days interval) again performed the best and provided (3.66 and 3.43 ton ha^{-1}) of yield at Bandarban and Rangamati, respectively. At Rangamati the yield of treatment T_3 was significantly different from all other treatments. The second highest rice grain yield was 3.09 ton ha^{-1} recorded from T_2 at Rangamati and was followed by T_1 and T_5 but significantly different from T_4 and untreated control which provided the least yield (1.99 ton ha^{-1}). Nevertheless, at Bandarban experimental jhum field the second highest grain yield was obtained from T_2 which was statistically at par with treatment T_3 and followed by treatment T_1 but statistically different from other treatments i.e., T_5, T_4 and T_6. The lowest rice grain yield (1.99, 1.96 and 1.96 ton ha^{-1}) were obtained from untreated control plot at Khagrachari, Bandarban and Rangamati, respectively those were statistically different from all other treatments at all hill experimental jhum fields.

In 2016 different chemicals and IPM provided percent yield increase over untreated control were ranged from 28.99-91.77. The order of effectiveness of five treatments over untreated control were

T_3>T_2>T_1>T_5>T_4. Jhumian people practice jhum cultivation during the monsoon period when the frequency of rainfall comparatively higher than other times. Jhumian people are not familiar with IPM practice thus all component were not efficiently used by them. Jhumian people failed to spray insecticide in the selected IPM plot. The result revealed that treatment IPM (T_4) did not perform well to suppress the insect pests and increase percent yield over untreated control.

4.5. Pest management approaches applied against major and promising insect and mite pest for rice of rice-cotton intercropping system in hill districts of Bangladesh

The experiment were conducted in the farmer's fields of Bandarban, Rangamati and Khagrachari from 2015 to 2016. The main target of the experiment was to develop sustainable and environment friendly management practices used against some major and promising insect mite & pests of rice in rice-cotton intercropping system in hill districts of Bangladesh. The results of the present study have been interpreted and discussed under the following sub-headings:

4.5.1 Effect of different management practices applied against promising insect pests of rice on rice of rice-cotton intercropping system

Effect of different management practices on rice of rice-cotton intercropping system and yield of rice varied significantly in experimental fields at Bandarban, Rangamati and Khagrachari districts from 2015 to 2016. Elaborate all the practices (1) $T_{1,}$ $T_{2,}$ $T_{3,}$ T_4 and untreated control. (2) Also $T_{1,}$ $T_{2,}$ $T_{3,}$ $T_{4,}$ T_5 and untreated control. The results have been presented below:

4.5.1.1 Effect of different management practices applied against rice bug on rice of rice-cotton intercropping system

In 2015, results indicated a considerable variation observed among the management practices in respect of the percent of grain infested panicle^{-1} plant^{-1} (Table 4.4.40). Grain damage were ranged from (1.94-6.98), (0.97-5.52) and (0.17-4.71) after panicle initiation till before the harvesting of rice crop at Bandarban, Rangamati and Khagrachari, respectively. The highest percent of damage were 6.98, 5.52 and 4.71 recorded from the untreated control plot which were significantly different from all other treatments at all three hill districts except treatments T_1 (5.94 and 4.17) at Bandarban and Khagrachari, respectively. Treatment T_3 performed the best among the other treatments and the lowest grain infestation which was (1.94) noted which significantly different from all other treatments except treatment T_2 (2.90) and followed by treatment T_4 (5.21) at Bandarban.

However at Rangamati the lowest percent of grain infestation was (0.97) recorded from treatment T_3 which was statistically different from all other treatments and followed by Treatments T_2 (1.93) T_4 (4.25) and T_1 (4.97). Comparable the lowest (0.17) percent of infestation was observed from treatment T_3 which was significantly different from all other treatments and followed by treatments T_2 (1.13) and T_4 (3.44) at Khagrachari. Again in 2015, the reduction percent of infested grain panicle^{-1} plant^{-1} over control were ranged from (8.33-70.24), (9.94-82.37) and (11.63-96.42) after panicle initiation to before harvesting of rice crop indicating the considerable protection from rice bug at Bandarban, Rangamati and Khagrachari, respectively.

Table 4.4.40 Effect of different management practices on rice in rice-cotton intercrop field applied against rice bug infestation at Bandarban, Rangamati and Khagrachari during 2015

Treatments	Mean percentage of rice bug infested grain panicle^{-1} plant^{-1}			Percent reduction infestation of rice bug infested grain panicle^{-1} plant^{-1}		
	Bandar-ban	Ranga-mati	Khagra-chari	Bandar-ban	Ranga-mati	Khagra-chari
T_1 = Farmers practice	5.94 ab	4.97 b	4.17 ab	8.33 d	9.94 d	11.63 d
T_2 = Spraying Actara 25 WG @ 0.5 g Liter^{-1} water at 25 days interval	2.90 c	1.93 d	1.13 c	55.79 b	65.05 b	76.13 b
T_3 = Spraying Voliam Flexi 300 SC @ 0.5ml Liter^{-1} water at 25 days interval	1.94 c	0.97 e	0.17 d	70.24 a	82.37 a	96.42 a
T_4 = IPM (Nappy+ Hand Weeding+ Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water apply when necessary)	5.21 b	4.25 c	3.44 b	19.55 c	23.03 c	26.96 c
T_5 = Untreated control	6.98 a	5.52 a	4.71 a	-	-	-
CV (%)	**10.55**	**5.39**	**13.52**	**5.62**	**10.71**	**4.60**

Data are the average of ten observations from 4 replications.
In a column, means followed by same letter(s) are not significantly different by Tukey's HSD test at $P<0.05$

The highest rate of reduction of infested grain plant^{-1} over control was recorded from treatment T_3 (70.24, 82.37 and 96.42) at Bandarban, Rangamati and Khagrachari, correspondingly those were statistically different from all other treatments of experimental fields of three hill districts and followed by treatments T_2 (55.79, 65.05 and 76.13), T_4 (19.55, 23.03 and 26.96) respectively like previously mentioned order.

Among the treatments farmers practice (T_1) achieved less reduction (8.33, 9.94 and 11.63) and a higher percent of grain infestation (5.94, 4.97, and 4.17) at Bandarban, Rangamati and Khagrachari, correspondingly. Results worked against rice bug infestation over control at all experimental fields of three hill districts those were statistically different from other treatments. Results suggested that Jhumian people should follow some effective treatments instead of their own practices.

In the year 2016, grain damage was ranged from (1.96 -2.62), (1.19 -2.49) and (2.27-3.90) after panicle initiation till before the harvest of rice crop at Bandarban, Rangamati and Khagrachari, respectively (Table 4.4.41).

Table 4.4.41: Effect of different management practices on rice grain in cotton-rice intercrop field applied against rice bug infestation at Bandarban, Rangamati and Khagrachari during 2016

Treatments	Mean percentage of rice bug infested grain panicle^{-1} plant^{-1}			Percent reduction infestation of rice bug infested grain panicle^{-1} plant^{-1}		
	Bandar-ban	Ranga-mati	Khagra-chari	Bandar-ban	Ranga-mati	Khagra-chari
T_1 = Spraying Marshal 20 EC @ 2 ml Liter^{-1} water at 25 days interval	2.08 b	1.66 b	3.06 bc	19.66 b	32.47 b	20.97 d
T_2 = Spraying Actara 25 WG @ 0.5 g Liter^{-1} water at 25 days interval	2.14 b	1.81 b	2.53 de	17.63 bc	26.60 c	34.70 b
T_3 = Spraying Voliam Flexi 300 SC @ 0.5ml Liter^{-1} water at 25 days interval	1.96 b	1.19 c	2.84 cd	24.29 a	51.82 a	26.75 c
T_4 = IPM (Nappy+ Hand Weeding+ Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water apply when necessary)	2.19 b	1.60 b	3.42 b	15.62 c	34.87 b	11.63 e
T_5 = Ripcord 10 EC @ 1.0 ml Liter^{-1} water at 25 days interval	1.93 b	1.22 c	2.27 e	25.73 a	50.37 a	41.40 a
T_6 = Untreated control	2.62 a	2.49 a	3.90 a	-	-	-
CV (%)	**7.17**	**6.77**	**6.82**	**5.89**	**5.56**	**6.54**

Data are the average of ten observations from 4 replications.
In a column, means followed by same letter(s) are not significantly different by Tukey's HSD test at $P<0.05$

The maximum percent of damages were (2.62), (2.49) and (3.90) significantly different from the untreated control which were significantly inconsistent from all other treatments at all three hill districts. Treatment T_5 performed the best among the other treatments and provided the lowermost the grain infestation (1.93) which was significantly at par with the treatments T_3, T_1, T_2, and T_4 having infestation of 1.96, 2.08, 2.14 and 2.19, respectively at Bandarban. At Rangamati the lowest percent of grain infestation was recorded 1.19 from treatment T_3 which was statistically different from all other treatments except treatments T_5 (1.22) and followed by treatments T_4, T_1 and T_2 having 1.60, 1.66, and 1.81 respectively, however, those were statistically at par with each other. Similarly to the lowest (2.27) percent of infestation was observed from treatment T_5 which was significantly different from all other treatments except T_2 (2.53) and followed by treatment T_3 and T_4. Among the treatments, T_4 provided the higher infestation (3.42) which was statistically identical with treatments T_1 (3.06) at Khagrachari.

The reduction of percent infested grain infested panicle^{-1} plant^{-1}over control were ranged from (15.62-25.73), (26.60-51.82) and (11.63-41.40) after panicle initiation till before the harvest of rice crop indicating the substantial protection from rice bug at Bandarban, Rangamati and Khagrachari, correspondingly during 2016. The highest rate of reduction of infestation of grain plant over control was recorded from treatment T_5 (25.73) at Bandarban which was significantly at par with treatments T_3 but different from treatment T_1, T_2 and T_4 having less reduction (15.62) of bug infestation over untreated control. At Rangamati the maximum reduction was 51.82 recorded from treatment T_3 which was significantly different from all other treatments except from treatment T_1 (50.37). The third uppermost reduction was 34.87 observed from treatment T_4 which was statistically similar with the treatment T_1 (32.47) and followed by treatment T_2 (26.60).

The highest rate of reduction of infested grain plant^{-1} over control was recorded from treatment T_5 (41.40) at Khagrachari which was significantly different from all other treatments. The second highest decline was (34.70) observed from treatment T_2 which was also statistically dissimilar from all other treatments and followed by the treatments T_3 (26.75) and was trailed by treatment T_1 (20.97). Among the treatments (T_4) IPM provided lower reduction of percent grain infested panicle^{-1} plant^{-1} over control (15.62 and 11.63) at Bandarban and Khagrachari respectively. Jhumian people do not familiar with the use of IPM components and sudden rainfall in hill region of Bangladesh might decline the effectiveness of chemical applied those apply just before.

4.5.1.2 Effect of different management practices against rice stem borer on rice of rice-cotton intercropping system

In 2015, results indicated that a variation observed among the management practices in respect of percent of damage by rice stem borer infested stems hill^{-1} (Table 4.4.42).

Stem damage were ranged from (0.88 -8.44), (0.89-8.43) and (0.23-7.32) before panicle initiation till harvest of rice crop at Bandarban, Rangamati and Khagrachari, respectively. The highest percent of damage were recorded from untreated control (T_5) which was significantly different from all other treatments at three hill districts. Treatment T_3 performed the best among between the other treatments and the lowest stem borer infestation was 0.88 and 0.23 which were significantly different from all other treatments except treatment T_2 (1.49 and 0.36) at Bandarban and Khagrachari, respectively followed by treatment T_4 (5.05 and 3.92).

Table 4.4.42 Effect of different management practices on rice in intercrop field applied against stem borer infestation at Bandarban, Rangamati and Khagrachari during 2015

Treatments	Mean percentage rice stem borer infested stem hill^{-1}			Percent reduction infestation of rice stem borer hill^{-1}		
	Bandar -ban	Ranga -mati	Khagra -chari	Bandar -ban	Ranga -mati	Khagra -chari
T_1 = Farmers practice	7.22 b	7.25 b	6.09 b	14.78 d	14.49 c	16.75 c
T_2 = Spraying Actara 25 WG @ 0.5 gm Liter^{-1} water at 25 days interval	1.49 d	1.50 d	0.36 d	82.55 b	82.24 a	95.05 a
T_3 = Spraying Voliam Flexi 300 SC @ 0.5ml Liter^{-1} water at 25 days interval	0.88 d	0.89 e	0.23 d	89.89 a	89.43 a	96.86 a
T_4 = IPM (Nappy+ Hand Weeding+ Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water apply when necessary)	5.05 c	5.06 c	3.92 c	39.19 c	40.12 b	46.37 b
T_5 = Untreated control	8.44 a	8.43 a	7.32 a	-	-	
CV (%)	11.56	5.44	11.59	5.72	9.79	4.06

Data are the average of ten observations from 4 replications.
In a column, means followed by same letter(s) are not significantly different by Tukey's HSD test at *$P<0.05$*

Among the treatments farmers' practice (T_1) performed poorly and resulted the uppermost percent of stem infestation of 7.22, 7.25 and 6.09 reported from the experimental fields at Bandarban, Rangamati and Khagrachari, respectively and significantly different from other treatments. Whereas at Rangamati similar observation was (0.89) recorded from treatment T_3 which was statistically different from all other treatments followed by treatments T_2 (1.50) and T_4 (5.06).

The reduction of percent rice stem borer infested stems hill^{-1} over control were ranged from (14.78 - 89.89), (14.49 -89.43) and (16.75 -96.86) before panicle initiation till harvest of rice crop indicating the considerable protection from rice stem borer at Bandarban, Rangamati and Khagrachari correspondingly. The highest rate of reduction of infestation of stem borer infested stems hill^{-1} over control was veried from treatment T_3 (89.89, 89.43 and 96.86) at Bandarban, Rangamati and Khagrachari and these were statistically different from all other treatments at Bandarban except at par with treatment T_2 (82.24 and 95.05) at Rangamati and Khagrachari correspondingly. Both Rangamati and Khagrachari the third maximum reduction were observed from treatments T_4 (40.12 and 46.37) and these were statistically different and followed by T_1 (14.49 and 16.75), respectively. Among the treatments farmers practice (T_1) achieved fewer reduction of rice stem borer infestation over control at all experimental fields of three hill districts and they were statistically different from other treatments. Results showed that Jhumian people might adopted particular sustainable treatments for recovering replaecing their own ethnic practices.

In 2016, stem borer damage were ranged from (4.26-12.93), (1.01-3.95) and (1.69-4.50) before panicle initiation till harvest of rice crop at Bandarban, Rangamati and Khagrachari respectively (Table 4.4.43). The highest percent damage 12.93, 3.95 and 4.50 were recorded from the untreated control and they were significantly different from all other treatments at all three hill districts. Results indicated that this rice stem borer infestation of the years were higher in intercrop rice fields than the jhum rice crop. At Bandarban the intercrop rice were significantly higher infestation recorded during year 2016.

Treatment T_3 performed but among the other treatments and the lowest stem borer infestation (4.26) was noted which was significantly different from all other treatments. The second lowermost infestation (7.76) was observed in treatment T_2 treated plot which was statistically identical to that of treatments T_4 T_1, and T_5 (8.72, 8.77 and 9.15), respectively at Bandarban. Treatment T_3 performed the best and the lowest percent of grain infestation (1.01) was recorded which was significantly different from all other treatments except treatment T_2 and T_1 (1.3 and 1.40) at Rangamati, respectively and was followed by treatments T_5 and T_4. At Rangamati the lowest percent of grain infestation (1.69) was recorded from treatment T_3 which was statistically different from all other treatments. The second lowest infestation (2.92) were revealed from T_5 which was statistically identical with treatment T_2 (3.15) and followed by treatments T_4 (3.45) and T_1 (3.77) at Khagrachari.

The reduction of percent of infested stem hill^{-1} over control was ranged from (26.37-65.73), (51.44 - 74.05) and (14.18-61.52) before panicle initiation till the harvest of rice crop indicating a considerable protection from rice stem borer at Bandarban, Rangamati and Khagrachari, respectively. The highest rate of reduction of infested stems hill^{-1} over control was recorded from treatment T_3 (33.65) at Bandarban which was statistically different from all other treatments. The second highest reduction (37.60) was revealed from the treatment T_2 which was also significantly different from other treatments. Stem borer infestation was considerably higher at Bandarban and among the treatments the lowest reduction (26.37) was achieve from treatments T_5 which was at par with treatments T_1 (29.43) and T_4 (29.86).

At Rangamati the maximum reduction (74.05) was recorded from treatment T_3 which was significantly similar with treatments T_2 (66.69) and followed by treatment T_1 (64.32). Among treatments the lowest reduction was (51.44) achieved from treatments T_4 which was at par with treatments T_5 (51.59) and both were statistically different from all other treatments. The highest and second maximum percent of reduction of infested stem hill^{-1} over control was documented once more from treatment T_3 and T_5 (61.52 and 33.56) at Khagrachari and the results of both treatments were significantly different from all other treatments. Whereas T_2 had this moderate percent of infestation over control (28.44) which was statistically different from other treatments and followed by T_4 and T_1 (21.48 and 14.18, respectively). Overall stem borer infestation was adequate at Bandarban and comparatively higher infestation were recorded at intercrop rice than jhum rice in 2015 & 2016. Furthermore, among the different treatments, T_3 comprised of spraying Voliam Flexi 300 SC @ 0.5ml Liter^{-1} water at 25 days interval were effective to suppress infestation and reduction of infestation over control unswervingly. Whereas other chemical treatments contributed in different way at three hill regions, and failed to demonstrate their effectiveness independently.

Table 4.4.43 Effect of different management practices on rice in cotton-rice intercrop field used against stem borer infestation at Bandarban, Rangamati and Khagrachari during 2016

Treatments	Mean percentage infestation of rice stem borer hill^{-1}			Percent reduction mean infestation of rice stem borer hill^{-1}		
	Bandar-ban	Ranga-mati	Khagra-chari	Bandar-ban	Ranga-mati	Khagra-chari
T_1 = Spraying Marshal 20 EC @ 2 ml Liter^{-1} water at 25 days interval	8.77 b	1.40 bc	3.77 b	29.43 c	64.32 b	14.18 e
T_2 = Spraying Actara 25 WG @ 0.5 g Liter^{-1} water at 25 days interval	7.76 b	1.31 c	3.15 cd	37.60 b	66.69 ab	28.44 c
T_3 = Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water at 25 days interval	4.26 c	1.01 c	1.69 e	65.73 a	74.05 a	61.52 a
T_4 = IPM (Nappy+ Hand Weeding+ Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water apply when necessary)	8.72 b	1.91 b	3.45 bc	29.86 c	51.44 c	21.48 d
T_5 = Ripcord 10 EC @ 1.0 ml Liter^{-1} water at 25 days interval	9.15 b	1.90 b	2.92 d	26.37 c	51.59 c	33.56 b
T_6 = Untreated control	12.93 a	3.95 a	4.50 a	-	-	-
CV (%)	**9.36**	**13.29**	**4.55**	**6.45**	**6.75**	**5.43**

Data are the average of ten observations from 4 replications.
In a column, means followed by same letter(s) are not significantly different by Tukey's HSD test at *P<0.05*

4.5.1.3 Effect of different management practices applied against grasshoppers on rice-cotton intercropping system

In 2015, the results indicated a considerable variation observed among the management practices in respect of the percent damage through infestation by grasshopper's infested leaves hill^{-1} (Table 4.4.44) by grasshopper.

Leaves damage were ranged from (16.97-52.05), (17.76-52.84) and (6.41-41.48) after rice plant arises till before the harvesting of rice crop at Bandarban, Rangamati and Khagrachari, respectively. The highest percent of leaves damag were 52.05, 52.84 and 41.48 recorded from the untreated control which were significantly different from all other treatments at all three hill districts except treatments (farmers practice) (49.55, 50.34 and 38.99). Treatment T_3 performed outstanding and the lowest most leave infestation was 16.97 and 6.41 recorded and this was which significantly different from all other treatments except treatment T_2 (21.39 and 10.83) at Bandarban and Khagrachari respectively and followed by treatments T_4 (42.63 and 32.07).

Table 4.4.44 Effect of different management practices on rice leaves in intercrop field applied against grasshopper infestation at Bandarban, Rangamati and Khagrachari during 2015

Treatments	Mean percentage of grasshopper infested leaves hill^{-1}			Percent reduction of grasshopper infested leaves hill^{-1}		
	Bandar-ban	Ranga-mati	Khagra-chari	Bandar-ban	Ranga-mati	Khagra-chari
T_1 = Farmers practice	49.55 a	50.34 a	38.99 a	7.97 c	4.73 c	6.02 d
T_2 = Spraying Actara 25 WG @ 0.5 g Liter^{-1} water at 25 days interval	21.39 c	22.18 c	10.83 c	55.15 b	58.02 a	73.89 b
T_3 = Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water at 25 days interval	16.97 c	17.76 d	6.41 c	65.75 a	66.39 a	84.55 a
T_4 = IPM (Nappy+ Hand Weeding+ Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water apply when necessary)	42.63 b	43.42 b	32.07 b	11.23 c	17.82 b	22.69 c
T_5 = Untreated control	52.05 a	52.84 a	41.48 a	-	-	-
CV (%)	**7.95**	**5.04**	**7.84**	**7.28**	**12.70**	**3.05**

Data are the average of ten observations from 4 replications.
In a column, means followed by same letter(s) are not significantly different by Tukey's HSD test at $P<0.05$

Whereas at Rangamati again T_3 treated plot had the lowest leaf infestation of 17.76 and which was statistically dissimilar from other treatments and followed by T_2 (22.18) and T_4 (43.42) at Khagrachari. Among the treatments, T_1 achieve the lowest infestation and followed by treatment T_4

having IPM (Nappy+ Hand Weeding+ Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water apply when necessary) performed unsatisfactory and had rate of higher infestation (42.63, 43.42 and 32.07) At Bandarban, Rangamati and Khagrachari.

The reduction percent of grasshoppers infested leaves hill^{-1} over control ranged from (7.97 -65.75), (4.73 -66.39) and (6.02 -84.55) after rice plant arises till before harvesting of rice crop at Bandarban, Rangamati and Khagrachari, respectively. The highest percent reduction of grasshopper infested leaves hill^{-1} over control was recorded from treatment T_3 (65.75, 66.39 and 84.55) at Bandarban, Rangamati and Khagrachari and those were statistically different from all other treatments except statistically similar with treatments T_2 (58.02) at Rangamati. The second highest percent reduction was obtained from treatments T_2 (55.15 and 73.89) at Bandarban, and Khagrachari, respectively and were significantly different from all other treatments.

In 2016, leave damage was ranged from (2.96 -10.7), (0.62 -2.46) and (1.45 -4.63) after rice plant arises till before harvesting of rice crop at Bandarban, Rangamati and Khagrachari, respectively (Table 4.4.45).

The highest percent of damaged (10.7, 2.46 and 4.63) but were recorded from the untreated control which were significantly different from all other treatments at all three hill districts, respectively. Treatment T_3 performed the best among all other treatments and the lowest leaf infestation was (2.96) recorded and which significantly different from all other treatments excluding T_5 (3.61) at Bandarban. The second lowest percent infestation was recorded from treatments T_1 which was significantly not different from T_4 (5.07) and followed by treatments $T_1$and T_2. At Rangamati the lowest percent grasshoppers infested leaves hill^{-1} was recorded (0.62) from treatment T_3 which was statistically at par with treatments T_2 but different from other treatments. The third lowermost infestation was (0.90) from treatment T_5 which was statistically identical with treatments T_2 (0.77) and T_1 (1.04) then followed by T_4 (1.47). Whereas at Khagrachari the second lowest percent of infestation was (1.45 and 1.88) recorded from treatments T_3 and T_5 respectively and both were significantly different from all other treatments. The third lowermost percent of infestation was 2.64 obtained from treatment T_4 which was statistically at per with treatment T_2 (2.57) and followed by treatment T_1 (3.20).

The reduction of the percent of grasshoppers infested leaves hill^{-1} over control was ranged from 38.79 -72.41, 40.05 -74.95 and 30.82-68.64 after rice plant arises till before harvest of rice crop at Bandarban, Rangamati and Khagrachari, respectively. The highest percent of reduction of grasshoppers infested leaves hill^{-1} over control was recorded from treatment T_3 (72.41) at Bandarban which was significantly different from all others treatments except T_5 (66.31).

Table 4.4.45 Effect of different management practices on rice leaves in cotton-rice intercrop field applied against grasshopper infestation at Bandarban and Rangamati, Khagrachari during 2016

Treatments	% of rice infestation of grasshopper hill^{-1}			% reduction of grasshopper infestation hill^{-1}		
	Bandar -ban	Ranga -mati	Khagra -chari	Bandar -ban	Ranga -mati	Khagra -chari
T_1 = Spraying Marshal 20 EC @ 2 ml Liter^{-1} water at 25 days interval	6.55 b	1.04 c	3.20 b	38.90 c	57.72 c	30.82 d
T_2 = Spraying Actara 25 WG @ 0.5 g Liter^{-1} water at 25 days interval	6.56 b	0.77 cd	2.57 c	38.79 c	68.77 b	44.51 c
T_3 = Spraying Voliam Flexi 300 SC @ 0.5ml Liter^{-1} water at 25 days interval	2.96 d	0.62 d	1.45 e	72.41 a	74.95 a	68.64 a
T_4 = IPM (Nappy+ Hand Weeding+ Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water apply when necessary)	5.07 bc	1.47 b	2.64 c	52.66 b	40.05 d	42.89 c
T_5 = Ripcord 10 EC @ 1.0 ml Liter^{-1} water at 25 days interval	3.61 cd	0.90 c	1.88 d	66.31 a	63.45 c	59.46 b
T_6 = Untreated control	10.71 a	2.46 a	4.63 a	-	-	-
CV (%)	**13.11**	**8.07**	**5.18**	**5.19**	**4.31**	**8.06**

Data are the average of ten observations from 4 replications.
In a column, means followed by same letter(s) are not significantly different by Tukey's HSD test at $P<0.05$

The third the higher reduction was 52.66 from treatment T_4 and statistically different from other treatments and followed by T_2 (38.79) and T_1 (38.90). Whereas at Rangamati maximum reduction was 76.85 recorded from treatment T_3 which was significantly different from all other treatments.

The second maximum reduction was 68.77 obtained from treatment T_2 which significantly different from other treatments followed by treatment T_5 and T_1 (63.45 and 57.72) individually. Among the treatments at Rangamati T_4 achieved comparatively the lowest reduction (40.05) over control which significantly dissimilar from other treatments. The highest and second uppermost reduction of grasshoppers infested leaf hill^{-1} over control was recorded from treatment T_3 and T_5 (68.64 and 59.46) respectively at Khagrachari, which was significantly different from other treatments. Whereas third uppermost reduction over control was (44.51) found in T_2 which was at par with treatments T_4 (42.89) and followed by treatment T_1 (30.82).

In intercrop field experiments, the infestation of grasshopper infestation was significantly higher 2015 than 2016. Between the cropping patterns, jhum crop is less susceptible than intercrop rice. Result also proved that more crop diversity at jhum reduce the grasshopper infestation at all hill district.

Among the chemical treatments, T_3 comprising spraying voliam flexi 300 SC @ 0.5ml liter^{-1} water at 25 days interval achieved the lower of grasshopper infestation which was significantly the lowest and reduction percent of infestation over untreated control and was satisfactory whereas other chemicals did perform steadily. In Bangladesh Jhumian people cultivate their hill land during the monsoon season in rainfed condition. During the monsoon sometimes heavy rainfall after spray and little precipitation might diminish the efficacy of chemicals at all the experimental hill districts.

4.5.1.4 Effect of different management practices against leaf folder on rice intercrop

In 2015, results indicated that considerable variation found among the management practices in respect of percent leaf folder infested leaves hill^{-1} (Table 4.4.46). Leaves damage were ranged from (2.96-0.98), (0.62-0.96) and (1.45-3.86) after rice plants arise till before harvesting of rice crop at Bandarban, Rangamati and Khagrachari, respectively. The highest percent of damage were (2.96, 0.62 and 1.45) recoreed from the untreated control which were significantly different from all other treatments at Bandarban and Rangamati respectively, but identical with T_1, T_4 and T_2 at Khagrachari.

Treatment T_3 performed the best and gave the lowest leaves infestation of 2.96 and 0.62 which was significantly different from all other treatments and followed by treatments T_2 (0.38 and 0.35), T_4 (0.58 and 0.549) at Bandarban and Rangamati, respectively. Among the treatment T_1 *i.e.*, farmers' practice couldn't achieve satisfactory outcomes *i.e.,* infestation were (0.87 and 0.85) both were statistically different from other treatments at Bandarban and Rangamati, respectively. The treatment T_1 showed the highest infestation and significantly at par with all other treatments including untreated control but significantly different from T_3.

The reduction percent of leaf folder infested leaves hill^{-1} over control was ranged from (7.78 -82.73), (11.42 -84.73) and (2.84 -21.04) after rice plant arises till before the harvest of rice crop at Bandarban, Rangamati and Khagrachari, correspondingly. The highest percent of reduction of leaf folder infested leaves hill^{-1} over control was recorded from treatment T_3 (82.73, 84.73 and 21.04) at Bandarban, Rangamati and Khagrachari, respectively. Those were statistically different from all other treatments. The second highest leaf folder infested leaves hill^{-1} over control were (61.75, 63.06 and 15.66) and those also statistically different from other treatments. Treatment T_4 *i.e.,* IPM include nappy+ hand weeding+ spraying voliam flexi 300 SC @ 0.5 ml liter^{-1} and water apply when necessary, achieved moderately reducing of leaf folder infested leaves hill^{-1} over control were (38.23, 42.77 and 10.62) which were statistically different from other treatments at Bandarban, Rangamati and Khagrachari, respectively.

Table 4.4.46 Effect of different management practices on rice in intercrop field applied against leaf folder infestation at Bandarban, Rangamati and Khagrachari during 2015

Treatments	Mean percentage leaf folder infested leaves hill^{-1}			Percent reduction infestation of leaf folder infested leaves hill^{-1}		
	Bandar -ban	**Ranga -mati**	**Khagra -chari**	**Bandar -ban**	**Ranga -mati**	**Khagra -chari**
T_1 = Farmers practice	0.87 b	0.85 b	3.75 ab	7.78 d	11.42 d	2.84 d
T_2 = Spraying Actara 25 WG @ 0.5 g Liter^{-1} water at 25 days interval	0.38 d	0.35 d	3.26 ab	61.75 b	63.06 b	15.66 b
T_3 = Spraying Voliam Flexi 300 SC @ 0.5ml Liter^{-1} water at 25 days interval	0.17 e	0.15 e	3.05 b	82.73 a	84.73 a	21.04 a
T_4 = IPM (Nappy+ Hand Weeding+ Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water apply when necessary)	0.58 c	0.549 c	3.45 ab	38.23 c	42.77 c	10.62 c
T_5 = Untreated control	0.98 a	0.96 a	3.86 a	-	-	-
CV (%)	6.35	6.61	10.19	7.29	8.26	8.26

Data are the average of ten observations from 4 replications.
In a column, means followed by same letter(s) are not significantly different by Tukey's HSD test at *$P<0.05$*

Among the treatments farmers practice (T_1) failed to achieve satisfactory results *i.e.,* the lowest of percent of reduction (7.78, 11.42 and 2.84) of leaf folder infested leaves hill^{-1} over control and which was significantly different from all other treatments. Results indicated that Jhumian people need a sustainable any method to replace for their present farmer's practices. In 2016 indicated a considerable variation observed among the management practices in respect of percent leaf folder infested leaves hill^{-1} was shown in Table 4.4.47. Leaves damage were ranged from (0.92-1.68), (0.27-1.02) and (0.03 -0.43) after rice plants arise till before harvesting of rice crop at Bandarban, Rangamati and Khagrachari, respectively. The highest percent of leaf folder infested leaves hill^{-1}were (1.68, 1.02 and 0.43) recorded from the untreated control plot which were significantly different from all other treatments at Bandarban and Rangamati, respectively.

Treatment T_2 showed the leaves infestation percent was 0.27 which was statistically similar with the treatments T_3 and T_1 (0.30 and 0.42) and followed by treatments T_5 and T_4 (0.54 and 0.60). Once again the lowest percent infestation was (0.03) obtained from treatment T_5 treated plot which was significantly different from all other treatments at Khagrachari. Whereas the second lowest infestation was (0.06) recorded from the treatment T_2 which was statistically at par with treatment T_3 (0.07) and followed by treatments T_1 and T_4 (0.13 and 0.23), respectively.

Table 4.4.47 Effect of different management practices on rice leaves in cotton-rice intercrop field applied against rice leaf folder infestation at Bandarban, Rangamati and Khagrachari during 2016

Treatments	Percentage infestation of rice leaf folder infestation hill^{-1}			Percent reduction infestation of rice leaf folder infestation hill^{-1}		
	Bandar-ban	Ranga-mati	Khagra-chari	Bandar-ban	Ranga-mati	Khagra-chari
T_1 = Spraying Marshal 20 EC @ 2 ml Liter^{-1} water at 25 days interval	0.92 b	0.42 cd	0.13 c	45.59 a	59.21 b	71.75 b
T_2 = Spraying Actara 25 WG @ 0.5 g Liter^{-1} water at 25 days interval	1.18 b	0.27 d	0.06 d	30.67 b	73.16 a	95.26 a
T_3 = Spraying Voliam Flexi 300 SC @ 0.5ml Liter^{-1} water at 25 days interval	1.07 b	0.30 d	0.07 d	36.31 b	71.15 a	75.97 b
T_4 = IPM (Nappy+ Hand Weeding+ Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water apply when necessary)	0.98 b	0.60 b	0.23 b	41.59 a	41.64 c	46.51 c
T_5 = Ripcord 10 EC @ 1.0 ml Liter^{-1} water at 25 days interval	1.19 b	0.54 bc	0.03 e	29.10 b	47.33 c	94.14 a
T_6 = Untreated control	1.68 a	1.02 a	0.43 a	-	-	-
CV (%)	**11.64**	**12.01**	**4.44**	**7.22**	**8.77**	**4.70**

Data are the average of ten observations from 4 replications.
In a column, means followed by same letter(s) are not significantly different by Tukey's HSD test at $P<0.05$

The reduction percent of leaf folder infested leaves hill^{-1} over control was ranged from (29.10-45.59), (41.64 -73.16) and (46.51-94.14) after rice plant arises till before harvesting of rice crop at Bandarban, Rangamati and Khagrachari correspondingly during 2016. The highest percent reduction of leaf folder infested leaves hill^{-1} over control was recorded from treatment T_1 (45.59) statistically at par with other treatments except for untreated control. Whereas at Rangamati the highest and second highest percent of reduction were (73.16 and 71.15) recorded from treatments T_2 and T_3 whice were statistically at per each other but dissimilar with other treatments. The third highest reduction was 59.21 revealed from the treatment T_1 which also statistically dissimilar with other treatments but followed by T_5 and T_4 (47.33 and 41.64). The highest percentage of reduction of leaf folder infested leaves hill^{-1} over control was recorded from treatment T_5 (45.59) which was statistically at par with treatment T_2 (95.26) but dissimilar with other treatments at Khagrachari. Treatment T_3 always perfumed best among the treatments. However, this rice intercrop of 2016, T_3 reduced moderately and statistically identical with that of T_1 (71.75) and followed by T_2 (46.51)

4.5.1.5 Effect of different management practices applied against flea beetle on rice of intercrop

Result of 2016, indicated a considerable variation observed among the management practices in respect of percent of flea beetle-infested leaves hill^{-1} (Table 4.4.48).

Leaf damage were ranged from (11.14-20.20), (9.48-12.59) and (8.33-11.88) after rice plants arise till maximum tillering stage of rice at Bandarban, Rangamati and Khagrachari, respectively. The highest percent of leaf damage were 20.20, 12.59 and 11.88 recorded from the untreated control which were significantly different from all other treatments at Bandarban but statistically at par with treatments T_4, T_1 and T_2 at Rangamati, respectively, whereas at Khagrachari only identical with treatment T_4 (10.40) statistically different from other treatments. Treatment T_3 performed best and lowest leaf infestation (11.14) was noted which significantly at par with all other treatments except treatment T_4 (14.95) at Bandarban. The second lowest percent of infestation was (12.90) recorded from treatment T_5 which also significantly at par with treatment T_1 (13.11) and T_2 (13.19) followed by T_4.

Table 4.4.48 Effect of different management practices on rice leaves in cotton-rice intercrop field applied against flea beetle infestation at Bandarban, Rangamati and Khagrachari during 2016

Treatments	Percentage leaves infestation of rice flea beetle hill^{-1}			Percent reduction leaves infestation of rice flea beetle hill^{-1}		
	Bandar -ban	Ranga -mati	Khagra -chari	Bandar -ban	Ranga -mati	Khagra -chari
T_1 = Spraying Marshal 20 EC @ 2 ml Liter^{-1} water at 25 days interval	13.11 bc	12.38 a	9.95 b-d	35.11 b	3.38 c	16.21 c
T_2 = Spraying Actara 25 WG @ 0.5 g Liter^{-1} water at 25 days interval	13.19 bc	12.58 a	10.03 bc	34.70 b	2.57 c	15.56 c
T_3 = Spraying Voliam Flexi 300 SC @ 0.5ml Liter^{-1} water at 25 days interval	11.14 c	9.48 b	8.73 cd	44.85 a	24.68 a	26.76 b
T_4 = IPM (Nappy+ Hand Weeding+ Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water apply when necessary)	14.95 b	11.28 ab	10.40 ab	26.01 c	10.37 b	12.47 d
T_5 = Ripcord 10 EC @ 1.0 ml Liter^{-1} water at 25 days interval	12.90 bc	9.638 b	8.33 d	36.12 b	23.69 a	29.87 a
T_6 = Untreated control	20.20 a	12.59 a	11.88 a	-	-	-
CV (%)	**8.29**	**8.59**	**7.31**	**7.01**	**7.73**	**6.46**

Data are the average of ten observations from 4 replications.
In a column, means followed by same letter(s) are not significantly different by Tukey's HSD test at $P<0.05$

However, at Rangamati the lowest percent of flea beetle infestation was recorded (9.48) from treatment T_3 which was statistically similar to that of treatments T_5 (9.638) and T_4 (11.28) but statistically different from treatment T_1 and T_2. Among the treatments comparatively lower performed were obtained from treatments T_2 and T_1 (12.58 and 12.38), respectively and that were statistically identical to that of untreated control. Whereas at Khagrachari among the treatments T_5 performed this pest and the lowest leaf infestation was (8.33) recorded which was significantly different from other treatments except the treatment T_3 and T_1 (8.73 and 9.95) separately. Furthermore, treatment T_1 (0.21) which was the third lowermost percent of infestation significantly at par with T_4 (0.24) and both were statistically different from other treatments. Comparatively higher leaf infestation was (10.40) observed from treatment T_4 which was statistically identical to that of treatments T_1 (9.95), T_2 (10.03) and untreated control. Even though flea beetle infestation at Khagrachari was scarce compared to Bandarban and Rangamati jhum experimental fields.

The reduction percent of flea beetle-infested leaves hill^{-1} over control was ranged from (26.01 -44.85), (2.57 -24.68) and (12.47 -29.87) after rice plant arises till the maximum tillering of rice crop at Bandarban, Rangamati and Khagrachari, respectively. The highest percent of reduction of flea beetle-infested leaves hill^{-1} over control was 44.85 recorded from treatment T_3 which was significantly different from all other treatments at Bandarban. The second maximum reduction was 36.12 revealed from treatment T_5 which was statistically at par with the treatments T_1 and T_2 (35.11 and 34.70) correspondingly and followed by treatment T_4 (26.01) which was also statistically identical to that of other treatments. The highest and second highest percent of reduction of flea beetle-infested leaves hill^{-1}over control were (24.68 and 23.69) documented from treatment T_3 and T_5, respectively and both were statistically identical but significantly different from other treatments and followed by treatment T_4 (10.37). Among the treatments, the lowest performance was (2.57) recorded from treatment T_2 which was statistically at par with treatment T_1 and they were significantly different from other treatments. At Khagrachari the highest and second uppermost reduction was (29.87 and 26.76) found from the treatments T_5 and T_3, respectively which was statistically different from each other and from other treatments. The third-highest reduction was (16.21) recorded from treatment T_1 which was statistically at par with treatment T_2 but statistically different from other treatments. The lowest reduction was 12.47 documented from treatment T_4. Flea beetle generally forage other leafy vegetables and decaying foliage on the soil. All experimental intercrop rice leaves tip were infested by tiny black flea beetle throughly scrapping chlorophyll content which results clear white streak giving the unhealthy appearance of rice fields. This infestation initiated during the early tillering stage and lasted till the maximum tillering stage of rice fields.

4.5.1.6 Effect of different management practices applied against different major and promising insect pests on rice grain yield in rice-cotton intercropping at hills of different experimental hill slope of CHT

Yield result of 2015 displayed a considerable deviation among the management practices in rice-cotton intercrop related rice grain yield ha^{-1} (Table 4.4.49). Data uncovered that all the different plots treated with different treatments were significantly higher than the untreated control during both the years *i.e.*, 2015 and 2016. Marketable rice grain yield ha^{-1} and percent of yield over untreated control in different treatments at experimental plots of Bandarban, Rangamati and Khagrachari districts are presented in Table (4.4.49 and 4.4.50). In jhum experimental fields during the first year *i.e.*, 2015 confirmed that the highest yield (4.22 t ha^{-1}) was recorded from T_3 (spraying Voliam Flexi 300 SC @ 0.5ml $Liter^{-1}$ water at 25 days interval) at Khagrachari, which was significantly different from all other treatments except statistically at per with treatment T_2 (spraying Actara 25 WG @ 0.5 g $Liter^{-1}$ water at 25 days interval).

Table 4.4.49 Effect of different management practices applied against different major and promising insect pests on rice yield in intercrop field at Bandarban, Rangamati and Khagrachari during 2015

Treatments	Marketable rice t ha^{-1}			Percent increase of yield over control		
	Bandar-ban	Ranga-mati	Khagra-chari	Bandar-ban	Ranga-mati	Khagra-chari
T_1 = Farmers practice	2.36 bc	2.47 c	2.60 bc	2.25 d	3.02 d	8.80 d
T_2 = Spraying Actara 25 WG @ 0.5 g $Liter^{-1}$ water at 25 days interval	3.61 a	3.62 a	3.73 a	56.48 b	50.67 b	55.88 b
T_3 = Spraying Voliam Flexi 300 SC @ 0.5ml $Liter^{-1}$ water at 25 days interval	3.95 a	3.95 a	4.22 a	71.32 a	64.51 a	76.33 a
T_4 = IPM (Nappy+ Hand Weeding+ Spraying Voliam Flexi 300 SC @ 0.5 ml $Liter^{-1}$ water apply when necessary)	2.83 b	2.98 b	3.03 b	22.46 c	24.13 c	26.84 c
T_5 = Untreated control	2.37 c	2.40 c	2.39 c	-	-	-
CV (%)	6.92	6.49	7.20	10.89	6.05	6.36

Data are the average of ten observations from 4 replications.
In a column, means followed by same letter(s) are not significantly different by Tukey's HSD test at $P<0.05$

Similarly the maximum seed yield (3.95 and 3.93 t ha^{-1}) were obtained from the treatment T_3 at Bandarban and Rangamati and those were statistically similar to that of treatments T_2. The third highest seed yield (3.03, 2.98 and 2.83 ton ha^{-1}) were obtained from the treatments (T_4) IPM (Nappy+

Hand Weeding+ Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water apply when necessary) at Khagrachari, Rangamati and Bandarban experimental jhum fields, respectively in the hill districts of Bangladesh and followed by the treatments T_1 (Farmers practice) and T_5 (untreated control) those were statistically identical. Untreated control plots at all experimental fields of three hill districts produced the lowest (2.40, 2.39, 2.37 t ha^{-1}) rice yield due to comparatively higher leaf feeding, stem borer and sucking insect pests infestation thus the number of an effective tiller and healthy grain per panicle were comparatively lower than the other treated plots at Rangamati, Khagrachari and Bandarban.

Result indicated that treatments T_1 (Farmers practice) didn’t performe satisfactorily in respect of rice grain yield compared to other treatments. Jhumian people might adopt other chemical management tools instead of their old aged traditional practices to sustainable increase the jhum crops production sustainabily.

Table 4.4.50 Effect of different management practices applied against different major and promising insect pests on rice yield in intercrop field at Bandarban, Rangamati and Khagrachari during 2016

Treatments	Marketable rice t ha^{-1}			Percent increase of yield over control		
	Bandar-ban	Ranga-mati	Khagra-chari	Bandar-ban	Ranga-mati	Khagra-chari
T_1 = Spraying Marshal 20 EC @ 2 ml Liter^{-1} water at 25 days interval	3.66 b	3.42 ab	3.78 ab	45.20 c	48.76 c	54.53 b
T_2 = Spraying Actara 25 WG @ 0.5 g Liter^{-1} water at 25 days interval	3.88 ab	3.59 ab	3.87 ab	53.620 b	56.28 b	58.42 b
T_3 = Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water at 25 days interval	4.22 a	3.92 a	4.36 a	67.193 a	70.76 a	78.42 a
T_4 = IPM (Nappy+ Hand Weeding+ Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water apply when necessary)	3.09 c	2.95 bc	3.18 bc	22.512 e	28.51 e	30.03 c
T_5 = Ripcord 10 EC @ 1.0 ml Liter^{-1} water at 25 days interval	3.42 bc	3.22 ab	3.89 ab	35.688 d	40.27 d	58.92 b
T_6 = Untreated control	2.52 d	2.30 c	2.45 c			
CV (%)	6.76	10.46	10.12	7.34	6.02	6.20

Data are the average of ten observations from 4 replications.
In a column, means followed by same letter(s) are not significantly different by Tukey’s HSD test at *P<0.05*

In 2015 different chemicals and IPM treatments percent of yield increase over untreated control was ranged from (2.25 -76.33). Though insect pest infestation comparatively lower at jhum intercrop fields than the hill valley, the order of effectiveness of four treatments over untreated control was $T_3>T_2>T_4>T_1\geq T_5$.

The second year (2016) showed extensive variation among the management practices in respect of rice grain yield tha^{-1} (Table 4.4.50). The result stated that marketable rice grain yield ton ha^{-1} at the experimental field of Khagrachari was the highest (4.36 t ha^{-1}) was recorded from treatment T_3 (spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water at 25 days interval), which was statistically at par with all other chemical treatments but different from T_4 i.e., (IPM (Nappy+ Hand Weeding+ Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water apply when necessary) and untreated control. Similar rice grain yield was obtained from Rangamati experimental jhum rice-cotton intercrop field. Whereas at Bandarban again the highest (4.22 t ha^{-1}) yield was recorded from treatment T_3 (spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water at 25 days interval), which was statistically at par with treatment T_2 but significantly different from other treatments.

The second highest grain yield was 3.88 t ha^{-1} harvested from the treatment T_2 (Spraying Actara 25WG @ 0.5 g Liter^{-1} water at 25 days interval) which was statistically identical with other chemical treatments i.e., T_1 and T_5 but significantly different with treatment T_4 *i.e.*, IPM (Nappy+ Hand Weeding+ Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water apply when necessary) and untreated control.

Yield at Khagrachari experimental jhum field was comparatively higher due to lower flea beetle infestation during the tillering stage. At that time the higher stem borer and rice bug infestation were observed in the experimental jhum fields of Bandarban and Rangamati. The untreated control provided with the lowest yield of 2.52, 2.30 and 2.45 t ha^{-1} at Bandarban, Rangamati and Khagrachari, respectively those were statistically different from all other treatments except T_4 *i.e.*, IPM (Nappy+ Hand Weeding+ Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water apply when necessary). In 2016 different chemicals and IPM treatment plots showed percent yield increase over untreated control ranged from 22.51 -78.42. The order of effectiveness of five treatments over untreated control was $T_3>T_2>T_1>T_5>T_4$. Result revealed that rice-cotton intercrop provided higher rice grain yield than normal jhum cultivation at all three hill districts experimental fields.

4.6 Pest management approaches applied against promising insect & mite pests for cotton in rice-cotton intercropping system at hill districts of Bangladesh

The experiment was conducted in the farmer's fields of Bandarban, Rangamati and Khagrachari from 2015 to 2016.

The main target of the study was to develop sustainable and environmentally friendly management practices against some major and promising insect mite pests infesting intercrop cotton of rice-cotton intercropping system at hill districts of Bangladesh. The results of the present study have been interpreted and discussed under the following sub-headings:

4.6.1 Effect of pest management approaches applied against insect & mite pests for cotton insect pests in the rice-cotton intercropping system in hill districts of Bangladesh

The experiment was conducted in the farmer's field at hill districts of Bandarban, Rangamati and Khagrachari from 2015 to 2016. The main target of the experiment was to study the effect of different management practices applied against insect & mite pests on cotton in rice-cotton intercrop in hill slope. The results have been discussed and interpreted in this section below:

4.6.1.1 Effect of different management practices against cotton aphid on intercrop field.

In 2015, results indicated a considerable variation among the management practices in respect of percent of aphid infested Leaves plant^{-1} (Table 4.4.51). Leaf damage was ranged from (4.71 -10.51), (1.90 -9.01) and (5.74 -11.54) after cotton plants arise till to before the harvest of cotton at Bandarban, Rangamati and Khagrachari, respectively.

The maximum percent of infestation were 10.51, 9.01 and 11.54 recorded from the untreated control from intercrop cotton at Bandarban, Rangamati and Khagrachari, respectively which were statistically different from all other treatments but statistically at par with the treatments T_1 and T_4 at Khagrachari. At Bandarban the lowest percent of aphid infested leaves plant^{-1} was recorded (4.71) from treatment T_3 which was statistically similar to that of treatment T_2 (5.38).

Comparatively higher percent of infestation was (8.78) observed from treatment T_1 which was significantly at par with treatment T_4 (8.17) but statistically different from other treatments. Again the lowest and the second lowest infestation were 1.90 and 2.92 recorded from the treatments T_3 and T_2 these were statistically different from all other treatments and followed by T_4 (5.74). Farmers' practice of Jhumian people (T_1) had higher infestation (7.98) which was statistically different from other treatments. On the other hand, at Khagrachari the lowest percent infestation was (5.74) recorded from treatment T_3 which was at par but numerically higher from treatments T_2 (6.42), and they were significantly different from treatments T_4 (9.21) and T_1 (9.76). The reduction of the percent of infested leaves plant^{-1} over control was ranged from (16.45 -55.19), (11.35 -78.87) and (15.50 -50.24) during the vegetative till to boll maturing period, indicating the considerable protection from aphid at Bandarban, Rangamati and Khagrachari, respectively. The highest rate of reduction of infestation over control was (55.19) recorded from treatment T_3 which was statistically different from other treatments. The second highest rate of reduction over control was (48.79) obtained from treatment T_2 which was statistically different from other treatments and followed T_4 (22.25) at Bandarban.

Table 4.4.51 Effect of different management practices on cotton leaves in intercrop field used against aphid infestation at Bandarban, Rangamati and Khagrachari during 2015

Treatments	Mean percent infestation of aphid leaves plant^{-1}			Mean percentage reduction infestation of leaves plant^{-1}		
	Bandar -ban	Ranga -mati	Khagra -chari	Bandar -ban	Ranga -mati	Khagra -chari
T_1 = Farmers practice	8.78 b	7.98 b	9.76 a	16.45 d	11.35 d	15.50 d
T_2 = Spraying Actara 25 WG @ 0.5 g Liter^{-1} water at 25 days interval	5.38 c	2.92 d	6.42 b	48.79 b	67.56 b	44.41 b
T_3 = Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water at 25 days interval	4.71 c	1.90 e	5.74 b	55.19 a	78.87 a	50.24 a
T_4 = IPM (Nappy+ Hand Weeding+ Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water apply when necessary)	8.17 b	5.74 c	9.21 a	22.25 c	36.17 c	20.26 c
T_5 = Untreated control	10.51 a	9.01 a	11.54 a	-	-	-
CV (%)	**6.48**	**6.31**	**12.66**	**5.04**	**7.52**	**6.08**

Data are the average of ten observations from 4 replications.
In a column, means followed by same letter(s) are not significantly different by Tukey's HSD test at $P<0.05$

The highest percent of reduction of infestation of infested leaves plant^{-1} over control was recorded from treatment T_3 (78.87 and 50.24) which was significantly different from all other treatments at Rangamati and Khagrachari, respectively. Yet again the second-highest percent of reduction over control (67.56 and 44.41) was observed from treatment T_2 which was significantly different from the treatments T_4 (36.17 and 20.26) followed by treatment T_1 (11.35 and 15.50) at Rangamati and Khagrachari, respectively. Among three hill districts, comparatively better reduction was observed at Rangamati sprayed chemical didn't washouts by sudden rain after applying on crops at intercrop experimental field.

In 2016, results indicated a considerable variation among the management practices in respect of the percent infested aphid leaves plant^{-1} (Table 4.4.52).

The reduction percent of aphid infested leaves plant^{-1} over control was ranged from (12.27 -26.95), (15.44 -30.60) and (7.57 -29.09) during the vegetative to boll maturing stage of intercrop cotton at Bandarban, Rangamati and Khagrachari, correspondingly.

The highest percent of infestation (26.95, 30.60 and 29.09) were recorded from the untreated control from experimental intercrop cotton although infestation was statistically different from all treatments at Bandarban, Rangamati and Khagrachari, respectively. At Bandarban lowest percent of aphid infestation was recorded (12.27) from treatment T_3 which was statistically equal with treatments T_1, T_4 and T_2 (13.78, 13.94 and 15.05) respectively similar to that of and followed by treatment T_5 (17.01). While Treatment T_5 relatively less effective and significantly similar to other treatments but statistically different from T_3. Whereas, at Rangamati treatment T_3 accomplished rather better and had minor infestation (15.44) which was statistically different from all other treatments. The second lowest infestation was (19.56) recorded from the treatment T_2 which was statistically identical with treatment T_1 and followed by T_5 (23.74) whereas treatment T_4 performed poorer than the other treatments hence higher infestation (25.91) was recorded. Among the treatments T_3 showed the lowest (7.57) aphid infestation at Khagrachari which was significantly at par with T_2 (11.46). Between the treatments at Khagrachari, treatment T_4 (15.54) was found less effective and significantly at par with the treatments T_1 and T_5 (14.58 and 13.98 respectively and followed by treatment T_2.

The reduction of total infested leaves plant^{-1} over control was ranged from (36.88 -54.48), (16.02 -49.95) and (46.59 -73.97) during the vegetative stage till the boll maturing stage of intercrop cotton indicating a substantial protection from aphid at Bandarban, Rangamati and Khagrachari. The highest percent reduction of infestation of aphid leaves plant^{-1} over control was recorded from treatment T_3 (54.48) which was statistically similar with T_1 and T_4 (48.86 and 48.27) respectively and followed by treatment T_2 (44.13). However, treatment T_5 achieved comparatively less reduction (36.88) which was statistically different from other treatments.

The highest percent reduction of infested leaves plant^{-1} over control was recorded once again from treatment T_3 (49.95) which was significantly different from all other treatments at Rangamati. Again next highest percent of reduction over control was (36.60) observed from treatment T_2 which was significantly different from the treatments T_1, T_5 and T_4 (29.28, 23.04 and 16.02) respectively. At Rangamati wide a range of reduction were found in T_5 (23.04) and T_4 (16.02) which were not treatments substantial as compared to other treatments.

Table 4.4.52 Effect of different management practices applied on aphid infestation on cotton leaves in intercrop field at Bandarban, Rangamati and Khagrachari during 2016

Treatments	Mean percent infestation of aphid leaves plant^{-1}			Mean percentage reduction infestation of leaves plant^{-1}		
	Bandar-ban	Ranga-mati	Khagra-chari	Bandar-ban	Ranga-mati	Khagra-chari
T_1 = Spraying Marshal 20 EC @ 2 ml Liter^{-1} water at 25 days interval	13.78 bc	21.82 cd	14.58 b	48.86 ab	29.28 c	49.88 c
T_2 = Spraying Actara 25 WG @ 0.5 g Liter^{-1} water at 25 days interval	15.05 bc	19.56 d	11.46 bc	44.13 b	36.60 b	60.59 b
T_3 = Spraying Voliam Flexi 300 SC @ 0.5ml Liter^{-1} water at 25 days interval	12.27 c	15.44 e	7.57 c	54.48 a	49.95 a	73.97a
T_4 = IPM (Nappy+ Hand Weeding+ Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water apply when necessary)	13.94 bc	25.91 b	15.54 b	48.27 ab	16.02 e	46.59 c
T_5 = Ripcord 10 EC @ 1.0 ml Liter^{-1} water at 25 days interval	17.01 b	23.74 bc	13.98 b	36.88 c	23.04 d	51.93 c
T_6 = Untreated control	26.95 a	30.60 a	29.09 a	-	-	-
CV (%)	**9.07**	**7.39**	**11.98**	**6.15**	**7.52**	**5.70**

Data are the average of ten observations from 4 replications.
In a column, means followed by same letter(s) are not significantly different by Tukey's HSD test at $P<0.05$

Whereas the highest and the second highest reduction (73.97and 60.59) were recorded from the treatments T_3 and T_2, respectively and they were statistically different from each other from all other treatments at Khagrachari. Although treatment T_4 (46.59) performed better at the experimental field of Khagrachari than Rangamati and Bandarban, but significantly at par with the treatments T_1 (49.88) and T_5 (51.93).

4.6.1.2 Effect of different management practices applied against cotton jassid in intercrop

In 2015, results indicated considerable variation among the management practices in respect of percent of jassid infested leaves plant^{-1} (Table 4.4.53).

Leaf damage was ranged from (2.04 -6.17), (3.55 -6.80) and (3.38 -7.27) after cotton plants arise till before harvesting of rice crop at Bandarban, Rangamati and Khagrachari, respectively.

The highest percent of infestation were 6.17, 6.80 and 7.27 recorded from the untreated control from experimental fields of intercrop cotton at Bandarban, Rangamati and Khagrachari, respectively which were statistically different from all other treatments but statistically at par with the treatments T_1 and T_4 at Bandarban, Rangamati and Khagrachari. The lowest percent of jassid infested leaves plant^{-1} was recorded (2.04, 3.55 and 3.38) from treatment T_3 which were statistically similar to that of treatment T_2 (2.59, 4.07 and 3.94) at Bandarban, Rangamati and Khagrachari, respectively. Comparable higher percent of infestation was (5.63, 6.49 and 6.98) observed in treatment T_1 which was significantly similar to that of treatment T_4 (5.52, 6.03 and 6.03) but statistically different from other treatments at Bandarban, Rangamati and Khagrachari, respectively. Again the second lowest infestation were (2.59, 4.07 and 3.94) revealed from the treatment T_2 and were statistically different from all other treatments but statistically identical with T_3 at Bandarban, Rangamati and Khagrachari, respectively. Farmers' practice of Jhumian people (T_1) revealed higher infestation of 5.63, 6.49 and 6.98 and those were also statistically different from with other treatments but statistically similar to that of T_4. Results indicating that both the treatments were less effective to suppress the jassid infestation on cotton leaves.

Table 4.4.53 Effect of different management practices applied on jassid infestation on cotton leaves in intercrop field at Bandarban, Rangamati and Khagrachari during 2015

Treatments	Mean percent infestation of jassid leaves plant^{-1}			Percent reduction jassid infestation of leaves plant^{-1}		
	Bandar -ban	Ranga -mati	Khagra -chari	Bandar -ban	Ranga -mati	Khagra -chari
T_1 = Farmers practice	5.63 a	6.49 a	6.98 a	8.72 c	4.59 d	3.97 c
T_2 = Spraying Actara 25 WG @ 0.5 g Liter^{-1} water at 25 days interval	2.59 b	4.07 b	3.94 b	57.96 b	40.18 b	45.77 b
T_3 = Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water at 25 days interval	2.04 b	3.55 b	3.38 b	66.99 a	47.81 a	53.44 a
T_4 = IPM (Nappy+ Hand Weeding+ Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water apply when necessary)	5.52 a	6.03 a	6.87 a	10.53 c	11.30 c	5.50 c
T_5 = Untreated control	6.17 a	6.80 a	7.27 a	-		-
CV (%)	**13.06**	**7.82**	**13.08**	**8.48**	**7.77**	**5.14**

Data are the average of ten observations from 4 replications.
In a column, means followed by same letter(s) are not significantly different by Tukey's HSD test at *P<0.05*

The reduction of the percent infested leaves plant^{-1} over control were ranged from (8.72 -66.99), (4.59 -47.81) and (3.97 -53.44) during the vegetative stage till the boll maturing stage which indicating the considerable protection from jassid at Bandarban, Rangamati and Khagrachari, correspondingly. The highest rate of reduction of infestation over control was (66.99, 47.81 and 53.44) recorded from treatment T_3 which were statistically different from other treatments at Bandarban, Rangamati and Khagrachari respectively. The second lowermost infestation over control was (57.96, 40.18 and 45.77) recorded from treatment T_2 which were statistically different from other treatments. Whereas treatments T_1 performed the lowest (8.72, 4.59 and 3.97) reduction over untreated control and those were statistically similar to T_4 (10.53, 11.30 and 5.50) at three hills experimental region.

In 2016, the results indicated a considerable variation among the management practices in respect of percent of infested jassid leaves plant^{-1} (Table 4.4.54). The reduction of percent jassid infested leaves plant^{-1} over control was ranged from (12.32 -26.50), (15.47 -29.85) and (7.57 -29.09) during the vegetative stage till the boll maturing stage of intercrop cotton at Bandarban, Rangamati and Khagrachari, correspondingly. The highest percent of infestation were (26.50, 29.85 and 29.09) recorded from the untreated control plot from experimental intercrop cotton although the infestation was statistically different from all other treatments at Bandarban, Rangamati and Khagrachari, respectively. At Bandarban the lowest mean percent of aphid infestation was recorded (12.32) from treatment T_3 which was statistically similar to that of treatments T_1, T_4 and T_2 (13.80, 13.94 and 14.05) respectively which was followed by treatment T_5 (16.98). While Treatment T_5 was relatively less effective and significantly alike with other treatments but statistically different from T_3.

Whereas, at Rangamati treatment T_3 accomplished rather better and had minor infestation (14.47) which was statistically different from all other treatments. The second lowest infestation was (19.59) revealed from the treatment T_2 which was statistically identical with treatment T_1 and followed by T_5 and T_4 (23.75 and 24.86), respectively. Whereas treatment T_4 performed poorer than the other treatments hence higher infestation (24.86) was resulted. Among the treatments T_3 again showed the lowest (7.57) jassid infestation which was significantly different from all other treatments. The second lowermost reduction over control was (11.46) recorded from the treatment T_2 which was statistically identical with treatments T_4 and T_1. Among the treatments at Khagrachari, treatment T_5 (15.54) was less effective but significantly at par with the treatment T_1 and T_4 (14.58 and 13.98), independently but different from other treatments.

The reduction of total infested leaves plant^{-1} over control was ranged from (35.95 -53.50), (16.70-50.28) and (46.59-73.97) at vegetative stage till the boll maturing stage of intercrop cotton indicating the substantial protection from jassid at Bandarban, Rangamati and Khagrachari, respectively.

The highest percent reduction of infestation of jassid leaves plant^{-1} over control was recorded from treatment T_3 (53.50) which was statistically similar to that of T_4 and T_1 (47.41 and 47.92, respectively) and followed by treatment T_2 (45.20). However, treatment T_5 achieve comparatively lower reduction (35.95) which was statistically different from other treatments but similar to that of treatment T_2. The highest percent of reduction of infested leaves plant^{-1} over control was recorded once again from treatment T_3 (50.28) which was significantly different from all other treatments at Rangamati. Again next highest percent of reduction over control was (34.37) observed from treatment T_2 which was significantly different from the treatments T_1, T_5 and T_4 (26.89, 20.43 and 16.70, respectively). Among the treatments at Rangamati wide range of reduction were seen but both T_5 and T_4 treatments achieved only 20.43 and 16.70 reduction over control, respectively. This was not substantial as to other treatments. Whereas the highest and second highest reduction (73.97 and 60.59) were recorded from the treatments T_3 and T_2, respectively though they were statistically different from each other and from all other treatments at Khagrachari. Whereas treatment T_4 (51.93) performed better at the experimental field of Khagrachari than Rangamati and Bandarban and these were significantly at par with the treatments T_1 (49.88) and T_5 (46.59).

Table 4.4.54 Effect of different management practices on cotton in cotton-rice intercrop field applied against jassid infestation at Bandarban, Rangamati and Khagrachari during 2016

Treatments	Mean percent infestation of jassid leaves plant^{-1}			Percent reduction jassid infestation of leaves plant^{-1}		
	Bandar -ban	Ranga -mati	Khagra -chari	Bandar -ban	Ranga -mati	Khagra -chari
T_1 = Spraying Marshal 20EC @ 2 ml Liter^{-1} water at 25 days interval	13.80 c	21.82 bc	14.58 bc	47.92 ab	26.89 c	49.88 c
T_2 = Spraying Actara 25WG @ 0.5 g Liter^{-1} water at 25 days interval	14.05 bc	19.59 c	11.46 c	45.20 bc	34.37 b	60.59 b
T_3 = Spraying Voliam Flexi 300SC @ 0.5ml Liter^{-1} water at 25 days interval	12.32 c	14.47 d	7.57 d	53.50 a	50.28 a	73.97 a
T_4 = IPM (Nappy+ Hand Weeding+ Spraying Voliam Flexi 300SC @ 0.5 ml Liter^{-1} water apply when necessary)	13.94 c	24.86 b	13.98 bc	47.41 ab	16.70 d	51.93 c
T_5 = Ripcord 10EC @ 1.0 ml Liter^{-1} water at 25 days interval	16.98 b	23.75 b	15.54 b	35.95 c	20.43 d	46.59 c
T_6 = Untreated control	26.50 a	29.85 a	29.09 a	-	-	-
CV (%)	**7.82**	**7.75**	**9.21**	**9.02**	**7.64**	**5.93**

Data are the average of ten observations from 4 replications.
In a column, means followed by same letter(s) are not significantly different by Tukey's HSD test at $P<0.05$

4.6.1.3 Effect of different management practices applied against whitefly on cotton plant in intercrop

In 2015, the results indicated a considerable variation among the management practices in respect of percent of whitefly infested leaves plant^{-1} (Table 4.4.55). Leaves damage were ranged from (5.81-9.77), (7.45-23.13) and (2.81-6.76) after cotton plants arised in the field till before the harvest of cotton at Bandarban, Rangamati and Khagrachari, respectively. The maximum percent of infestation were (9.77, 23.13 and 6.76) recorded from the untreated control from experimental intercrop cotton at Bandarban, Rangamati and Khagrachari, respectively which were statistically different from all other treatments but statistically at par with the treatments T_4 (9.56 and 6.57) and T_1 (9.27 and 6.26) at Bandarban and Khagrachari, respectively. The lowest percent of whitefly infested leaves plant^{-1} was recorded 5.81, 7.45 and 2.81 from treatment T_3 which were statistically similar to that of treatment T_2 (6.90 and 9.22) at Bandarban and Rangamati, respectively whereas at Khagrachari it was significantly different from all other treatments. Furthermore, the second lowest percent of infestation was 3.90 revealed from the treatment T_2 which was significantly different from other treatments at Khagrachari. At Rangamati the percent of whitefly infested leaves plant^{-1} was higher than the other two regions. The third-highest percent of infestation was 17.98 revealed from the treatment T_4 which was statistically identical with the treatment T_1 (18.69) and significantly different from other treatments. Results indicating that treatments T_4, T_1, IPM and farmers practice were less effective to suppress the whitefly infestation on cotton leaves at all three experimental fields of hill districts.

The reduction of the percent of infested leaves plant^{-1} over control was ranged from (2.11-40.52), (19.19-67.80) and (3.04-58.50) during the vegetative stage till the boll maturing stage indicating the considerable protection from whitefly at Bandarban, Rangamati and Khagrachari, respectively.

The highest rate of reduction of infestation over control was (40.52, 67.80 and 58.50) recorded from treatment T_3 which were statistically different from other treatments at Bandarban, Rangamati and Khagrachari, respectively. The second lowest infestation over control was (29.34, 60.13 and 42.36) from treatment T_2 which were statistically different from other treatments. Whereas treatments T_4 and T_1 had the lowest reduction over untreated control and those were statistically similar at three hill experimental region.

In 2016, results indicated comparatively lower infestation in all experimental fields than the previous year 2015. Considerable variation was observed among the management practices in respect of the percent of infested whitefly leaves plant^{-1} (Table 4.4.56). The reduction percent of whitefly infested leaves plant^{-1} over control ranged from (0.20 -2.54), (0.66-3.26) and (0.51 -2.26) at the vegetative stage till the boll maturing stage period of intercrop cotton at Bandarban, Rangamati and Khagrachari, correspondingly. The highest percent of infestation were 2.54, 3.26 and 2.26 recorded from the untreated control from experimental intercrop cotton although infestation was statistically different from all treatments at Bandarban, Rangamati and Khagrachari, correspondingly. At Bandarban the lowest percent of whitefly infestation was recorded (0.20) from treatment T_2 which was statistically dissimilar from other treatments. The second lowermost infestation was (0.33) recorded from the treatment T_3 which was statistically similar to that of with T_1, T_4 and T_5 (0.36, 0.39 and 0.45), respectively.

Table 4.4.55 Effect of different management practices on cotton in intercrop field applied against whitefly infestation at Bandarban, Rangamati and Khagrachari during 2015

Treatments	Mean percent infestation of whitefly leaves plant^{-1}			Percent reduction whitefly infestation of leaves plant^{-1}		
	Bandar -ban	**Ranga -mati**	**Khagra -chari**	**Bandar -ban**	**Ranga -mati**	**Khagra -chari**
T_1 = Farmers practice	9.27 a	18.69 b	6.26 a	5.04 c	19.19 c	7.28 c
T_2 = Spraying Actara 25 WG @ 0.5 g Liter^{-1} water at 25 days interval	6.90 b	9.22 c	3.90 b	29.34 b	60.13 b	42.36 b
T_3 = Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water at 25 days interval	5.81 b	7.45 c	2.81 c	40.52 a	67.80 a	58.50 a
T_4 = IPM (Nappy+ Hand Weeding+ Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water apply when necessary)	9.56 a	17.98 b	6.57 a	2.11 c	22.25 c	3.04 c
T_5 = Untreated control	9.77 a	23.13 a	6.76 a	-		-
CV (%)	**9.05**	**10.63**	**7.08**	**13.94**	**5.33**	**7.43**

Data are the average of ten observations from 4 replications.
In a column, means followed by same letter(s) are not significantly different by Tukey's HSD test at $P<0.05$

Whereas, at Rangamati treatment T_3 accomplished rather and resulted minor infestation (0.66) which was statistically different from all other treatments. The second lowest infestation was (0.87) recorded from the treatment T_2 which was statistically similar to that of treatment T_5 (0.98) and followed by T_1 (1.05). Whereas treatment T_4 performed poorly than the other treatments and hence resulted comparatively higher infestation (1.33). Among the treatments at Khagrachari T_2 again shown the lowest whitefly infestation which was (0.51) statistically identical with treatments T_1 and T_4 (0.55 and 0.60), respectively and followed by treatment T_5 (0.74). Among the treatments at Khagrachari, treatment T_4 (1.23) was less effective and significantly different from other treatments.

The reduction of total infested leaves plant^{-1} over control was ranged from (82.29-91.81), (59.12 - 79.69) and (45.85-77.65) at the vegetative stage till the boll maturing stage period of intercrop cotton indicating the substantial protection from whitefly at Bandarban, Rangamati and Khagrachari, correspondingly. The highest percent of reduction of infestation of whitefly leaves plant^{-1} over control recorded from treatment T_2 (91.81) which was statistically similar but numerically higher than other treatments. Results indicated that whitefly infestation was very low in comparison to previous year thus the treatment effect was not clear enough. The highest percent of reduction of infested leaves plant^{-1} over control was recorded from treatment T_3 (79.69) which was significantly different from all other treatments except T_2 (73.23) at Rangamati. The second-highest reduction percent over control recorded from T_2 which was significantly at par with treatments T_5 and T_1 (70.08 and 67.71), respectively but different from treatment T_4. Among the treatments, at Rangamati wide range of reduction were evident but T_4 treatment achieved only (45.85) reduction over control which was not substantial as accomplished from other treatments.

Table 4.4.56 Effect of different management practices on cotton in cotton-rice intercrop field applied against whitefly infestation at Bandarban, Rangamati and Khagrachari during 2016

Treatments	Mean percent infestation of whitefly leaves plant^{-1}			Percent reduction whitefly infestation of leaves plant^{-1}		
	Bandar -ban	Ranga -mati	Khagra -chari	Bandar -ban	Ranga -mati	Khagra -chari
T_1 = Spraying Marshal 20 EC @ 2 ml Liter^{-1} water at 25 days interval	0.36 b	1.05 c	0.55 cd	85.74 a	67.71 b	75.85 a
T_2 = Spraying Actara 25 WG @ 0.5 g Liter^{-1} water at 25 days interval	0.20 c	0.87 d	0.51 d	91.81 a	73.23 ab	77.65 a
T_3 = Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water at 25 days interval	0.33 b	0.66 e	0.60 cd	86.87 a	79.69 a	73.80 a
T_4 = IPM (Nappy+ Hand Weeding+ Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water apply when necessary)	0.39 b	1.33 b	1.23 b	84.76 a	59.12 c	45.85 b
T_5 = Ripcord 10 EC @ 1.0 ml Liter^{-1} water at 25 days interval	0.45 b	0.98 cd	0.74 c	82.29 a	70.08 b	67.23 a
T_6 = Untreated control	2.54 a	3.26 a	2.26 a	-	-	-
CV (%)	**6.51**	**5.51**	**10.44**	**5.31**	**5.04**	**7.01**

Data are the average of ten observations from 4 replications.
In a column, means followed by same letter(s) are not significantly different by Tukey's HSD test at $P<0.05$

Whereas the highest, second and third highest reduction (77.65, 75.85, and 73.80) were revealed from the treatments T_2, T_1 and T_3, respectively and was followed by treatment T_5 (67.23) and these were statistically identical at Khagrachari. Whereas treatment T_4 (45.85) performed poorly at the experimental field of Khagrachari which was statistically different from other treatments.

4.6.1.4 Effect of different management practices applied against red cotton bug on cotton in intercrop

In 2015, the results indicated a considerable variation among the management practices in respect of percent infested boll plant^{-1} (Table 4.4.57). Cotton boll staining was ranged from (1.32-4.11), (5.19-7.81) and (2.37-5.15) after cotton boll arises till before harvest of intercrop cotton at Bandarban, Rangamati and Khagrachari, respectively. The maximum percent of infestation were (4.11, 7.81 and 5.15) recorded from the untreated control plot from experimental intercrop cotton at Bandarban, Rangamati and Khagrachari, respectively which were statistically different from all other treatments but at par with the treatments T_1 and T_4 at Bandarban, Rangamati and Khagrachari. The lowest percent of infested boll plant^{-1} was recorded (1.32, 5.19 and 2.37) from treatment T_3 which were statistically equivalent with treatment T_2 (1.83, 5.64 and 2.88) at Bandarban, Rangamati and Khagrachari, respectively. Comparable higher percent of infestation were (3.72, 7.07 and 4.77) obtained from treatment T_4 which was significantly at par with treatment T_1 (3.81, 7.34 and 4.86) at Bandarban, Rangamati and Khagrachari, respectively. Farmers practice of Jhumian people revealed higher infestation and were (3.81, 7.34 and 4.86) and those were also statistically different from other treatments but at par with T_4 and untreated control. Results indicating that both the treatments were less effective to suppress the red cotton bug infestation on cotton boll.

The reduction of percent infested leaves plant^{-1} over control was ranged from (7.11-67.76), (6.02 - 33.53) and (5.67 -54.01) at the boll setting till the boll maturing stage period indicating the considerable protection from jassid at Bandarban, Rangamati and Khagrachari, congruently. The highest rate of reduction of infestation over control was (67.76, 33.53 and 54.01) recorded from treatment T_3 which were statistically different from other treatments at Bandarban, Rangamati and Khagrachari, correspondingly. The second lowermost reduction of infestation over control was (55.35, 27.70 and 44.12) recorded from treatment T_2 which was statistically different from other treatments. Whereas treatments T_1 had the lowermost rate (7.11, 6.02 and 5.67) reduction over untreated control and those were statistically similar to that of T4 (9.29, 9.45 and 7.41) at three hills experimental region.

Table 4.4.57 Effect of different management practices on cotton boll in intercrop field applied against red cotton bug infestation at Bandarban, Rangamati and Khagrachari during 2015

Treatments	Mean percentage of boll infested boll plant^{-1}			Percent reduction infestation of plant^{-1}		
	Bandar -ban	**Ranga -mati**	**Khagra -chari**	**Bandar -ban**	**Ranga -mati**	**Khagra -chari**
T_1 = Farmers practice	3.81 a	7.34 ab	4.86 a	7.11 c	6.02 c	5.67 c
T_2 = Spraying Actara 25 WG @ 0.5 g Liter^{-1} water at 25 days interval	1.83 b	5.64 bc	2.88 b	55.35 b	27.70 b	44.12 b
T_3 = Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water at 25 days interval	1.32 b	5.19 c	2.37 b	67.76 a	33.53 a	54.01 a
T_4 = IPM (Nappy+ Hand Weeding+ Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water apply when necessary)	3.72 a	7.07 ab	4.77 a	9.29 c	9.45 c	7.41 c
T_5 = Untreated control	4.11 a	7.81 a	5.15 a	-		-
CV (%)	**11.47**	**11.70**	**9.40**	**6.30**	**9.14**	**4.41**

Data are the average of ten observations from 4 replications.
In a column, means followed by same letter(s) are not significantly different by Tukey's HSD test at $P<0.05$

In 2016, the results indicated a considerable variation among the management practices in respect of percent infested boll plant^{-1} (Table 4.4.58). The percent infested boll plant^{-1} were ranged from (13.70 - 32.94), (22.46 -48.17) and (15.99 -31.15) at the boll setting stage till the boll maturing stage of intercrop cotton at Bandarban, Rangamati and Khagrachari, respectively.

The highest percent of infestation were (32.94, 48.17 and 31.15) recorded from the untreated control of experimental intercrop cotton although infestation rate was statistically different from all the treatments at Bandarban, Rangamati and Khagrachari, correspondingly. At Bandarban the lowest percent of red cotton bug stained boll were recorded (13.70) from treatment T_3 which was statistically similar to with treatments T_2 (17.62) and followed by treatment T_1, T_5 and T_4 (18.74, 19.74 and 21.15), respectively. While Treatment T_4 was less effective and significantly alike to that of other treatments but statistically different from T_3. Whereas, at Rangamati, treatment T_3 accomplished rather better and minor infestation (22.46) resulted and which was statistically different from treatment T_4 but at par with treatments T_2, T_1 and T_5 (26.30, 27.66 and 28.14), respectively. Among the treatments T_3 again showed the lowest (15.99) red cotton bug staining boll at Khagrachari which was significantly identical with all other treatments except untreated control. Among the treatments at Khagrachari, all the treatments performed well to suppress the infestation numerically at lower level.

Table 4.4.58 Effect of different management practices on cotton boll in cotton-rice intercrop field applied against red cotton bug infestation at Bandarban, Rangamati and Khagrachari during 2016

Treatments	Mean percentage of boll infested boll plant^{-1}			Percent reduction infestation of plant^{-1}		
	Bandar-ban	Ranga-mati	Khagra-chori	Bandar-ban	Ranga-mati	Khagra-chori
T_1 = Spraying Marshal 20EC @ 2 ml Liter^{-1} water at 25 days interval	18.74 b	27.66 bc	18.50 b	43.11 bc	42.82 bc	40.62 bc
T_2 = Spraying Actara 25WG @ 0.5 gm Liter^{-1} water at 25 days interval	17.62 bc	26.30 bc	17.52 b	46.51 b	45.36 b	43.77 ab
T_3 = Spraying Voliam Flexi 300SC @ 0.5ml Liter^{-1} water at 25 days interval	13.70 c	22.46 c	15.99 b	58.42 a	53.38 a	48.68 a
T_4 = IPM (Nappy+ Hand Weeding+ Spraying Voliam Flexi 300SC @ 0.5 ml Liter^{-1} water apply when necessary)	21.15 b	29.27 b	19.37 b	35.78 d	39.31 c	37.83 c
T_5 = Ripcord 10EC @ 1.0 ml Liter^{-1} water at 25 days interval	19.74 b	28.14 bc	18.50 b	40.06 cd	41.59 bc	40.61 bc
T_6 = Untreated control	32.94 a	48.17 a	31.15 a	-	-	-
CV (%)	**9.82**	**8.79**	**7.95**	**5.40**	**5.99**	**5.91**

Data are the average of ten observations from 4 replications.
In a column, means followed by same letter(s) are not significantly different by Tukey's HSD test at $P<0.05$

The reduction of total infested leaves plant^{-1} over control was ranged from (35.78 -58.42), (39.31 -53.38) and (37.83 -48.68) at the boll setting stage till the boll maturing stage of intercrop cotton indicating the substantial protection from red cotton bug at Bandarban, Rangamati and Khagrachari, respectively. The highest percent reduction of infestation of red cotton bug staining boll plant^{-1} over control was recorded from treatment T_3 (58.42) which was statistically different from all other treatments at Bandarban. Whereas the second highest reduction was (46.51) recorded from treatment T_2 which was statistically at par with treatment T_1 (43.11) and followed by treatments T_5 (40.06). Among the treatments, T_4 achieved only 35.78 reduction over control which was not substantial accomplishment compared from other except T_5. The highest percent of reduction of red cotton bug staining boll plant^{-1} over control was recorded from treatment T_3 (53.38) which was significantly different from all other treatments at Rangamati. Again the next highest percent reduction over control was (45.36) recorded from treatment T_2 which was significantly at par with treatments T_5 and T_1 (41.59 and 42.82), respectively but different from treatment T_4 (39.31). Whereas the highest and the second highest reduction (48.68 and 43.77) were recorded from the treatments T_3 and T_2 respectively and they were statistically identical with each other and followed by treatments T_1 and T_5 (40.62 and 40.61). Respectively at Khagrachari. Whereas treatment T_4 (37.83) performed poorly at the experimental field of Khagrachari which was statistically different from T_3 and T_2 but statistically at par with the treatments T_1 and T_5 (40.62 and 40.61), respectively.

4.6.1.5 Effect of different management practices used against cotton spotted bollworm in intercrop

In 2015, outcomes indicated a considerable variation among the management practices in respect of number at infested boll^{-5} plant^{-1} (Table 4.4.59).

Mean number of cotton boll damagewere ranged recorded from (0.10 -0.37), (0.49-2.41) and (0.11-0.33) after cotton boll arises till before the maturing of intercrop cotton at Bandarban, Rangamati and Khagrachari, respectively. The highest mean number of infestation were (0.37, 2.41and 0.33) recorded from untreated control plot, experimental intercrop cotton at Bandarban, Rangamati and Khagrachari, respectively which were statistically different from all other treatments but at par with the treatments T_1 and T_4 at Bandarban and Khagrachari, respectively. The lowest mean number of boll infested boll^{-5} plant^{-1} were recorded (0.10) from treatment T_3 which were statistically different from all other treatments and followed by treatment T_2 (0.17) at Bandarban. Whereas at Khagrachari the lowest mean number of infestation was (0.11) obtained from treatment T_2 which were statistically different from all other treatments and followed by treatment T_3 (0.16). Comparable higher percent of infestation were (0.34 and 0.36) observed from treatment T_1 which was significantly at par with treatment T_4 (0.32 and 0.31) at Bandarban and Khagrachari, respectively which was statistically at par with untreated control.

However, at Rangamati comparatively higher of infestation was observed than other two hill districts and again the lowest and the second lowest infestation was (0.49 and 0.80) recorded from T_3 and T_2, respectively and both were statistically different from each other as well as all other treatments. Farmers practice of Jhumian people (T_1) revealed again the higher infestation (0.34, 1.80 and 0.36) but those were also statistically identical with T_4 (0.32, 1.57 and 0.31) and untreated control at Bandarban, Rangamati and Khagrachari. Results indicating both treatments were less effective to suppress the spotted bollworm infestation on cotton boll.

The reduction the percent of infested leaves plant^{-1} over control was ranged from (8.66-72.80), (25.27-79.78) and (7.98-73.49) during the boll setting stage till the boll maturing stage indicating the considerable protection from spotted bollworm at Bandarban, Rangamati and Khagrachari, congruently.

Table 4.4.59 Effect of different management practices on cotton boll in intercrop field applied against spotted bollworm infestation at Bandarban, Rangamati and Khagrachari during 2015

Treatments	Mean number boll infested boll^{-5} plant^{-1}			Percent reduction infestation of number infested boll^{-5} plant^{-1}		
	Bandar-ban	Ranga-mati	Khagra-chori	Bandar-ban	Ranga-mati	Khagra-chori
T_1 = Farmers practice	0.34 a	1.80 b	0.36 a	8.66 c	25.27 d	7.98 c
T_2 = Spraying Actara 25WG @ 0.5 g Liter^{-1} water at 25 days interval	0.17 b	0.80 c	0.11 c	54.60 b	66.82 b	73.49 a
T_3 = Spraying Voliam Flexi 300SC @ 0.5ml Liter^{-1} water at 25 days interval	0.10 c	0.49 d	0.16 b	72.80 a	79.78 a	55.12 b
T_4 = IPM (Nappy+ Hand Weeding+ Spraying Voliam Flexi 300SC @ 0.5 ml Liter^{-1} water apply when necessary)	0.32 a	1.57 b	0.31 a	13.63 c	34.96 c	13.76 c
T_5 = Untreated control	0.37 a	2.41 a	0.33 a	-		-
CV (%)	**10.78**	**7.53**	**10.56**	**12.49**	**5.38**	**14.62**

Data are the average of ten observations from 4 replications.
In a column, means followed by same letter(s) are not significantly different by Tukey's HSD test at *P<0.05*

The highest rate of reduction of infestation over control was (72.80 and 79.78) recorded from treatment T_3 at Bandarban and Rangamati respectively and both treatments were statistically different from other treatments. The second lowest infestation over control were (54.60 and 66.82) from treatment T_2 which were statistically different from other treatments. Whereas at Khagrachari the highest rate of reduction of infestation over control was (73.49) from treatment T_2 and significantly different from all other treatments. Whereas treatments T_1 had the lowest (8.66 and 25.27) reduction over untreated control and those were statistically similar to that of T_4 (13.63 and 34.96) at Bandarban and Khagrachari, respectively. Furthermore at Rangamati T_1 resulted the lowest (7.98) reduction over control which was statistically different from all other treatments and followed by treatment T_4 (34.96).

In 2016, results indicated a considerable variation among the management practices in respect of infested boll^{-5} plant^{-1} (Table 4.4.60). Mean number infested boll^{-5} plant^{-1} ranged from (0.02-0.99), (0.12-2.91) and (0.06-2.05) at the boll setting stage till the boll maturing stage period of intercrop cotton at Bandarban, Rangamati and Khagrachari, respectively. The highest infestation were 0.99, 2.91 and 2.05 recorded from the untreated control recorded from experimental intercrop cotton although the infestation was statistically different from all treatments at Bandarban, Rangamati and Khagrachari, respectively except treatment T_4 at Bandarban. At Bandarban the lowest number infested boll^{-5} plant^{-1}was recorded (0.02) from treatment T_2 which was statistically similar to that of treatments T_3, T_5, and T_1 (0.04, 0.05 and 0.06), respectively and different from treatments T_4 (0.32) and untreated control. Whereas, at Rangamati treatment T_3 accomplished rather better and minor infestation (0.12) was resulted which was statistically different from other treatment. The second lowest infestation was (0.53) revealed from treatments T_1 which was significantly identical with treatment T_2 but different from other treatments. However, the lowest efficacy was (1.50) recorded from treatment T_4 which was statistically identical with treatment T_5 but different from other treatments. Among the treatments T_3 had shown the lowest (0.06) spotted bollworm infestation at Khagrachari which was statistically different from other treatment. The second lowest infestation was (0.74) recorded from treatments T_2 which was statistically identical with treatment T_1 but different from other treatments. However again the lowest efficacy was (0.95) recorded from treatment T_4 which was significantly identical with treatment T_5 but different from other treatments.

The reduction of total infested boll^{-5} plant^{-1} over control was ranged from (2.26 -97.47), (59.66 - 99.29) and (53.77 -96.90) during the boll setting stage till the boll maturing stage of intercrop cotton. This indicating the substantial protection from spotted bollworm at Bandarban, Rangamati and Khagrachari, correspondingly. The highest percent of reduction of infested boll^{-5} plant^{-1} over control was (97.47) recorded from treatment T_2 which was statistically at par with treatments T_3, T_5 and T_1 (97.80, 97.44 and 91.08) respectively *i.e.,* use of chemical treatments might be effective to suppress the infestation rate than IPM.

Among the treatments, T_4 achieved only (2.26) percent reduction over control and were not substantial as compared to other treatments as well as statistically different from all other treatments. Whereas the highest and the second highest reduction (99.29 and 89.20) were recorded from the treatments T_3 and T_1, respectively and than were statistically identical with each other and different from other treatments at Rangamati. Furthermore, the third-highest reduction was (67.69) revealed from the treatment T_2 which was statistically identical to that of T_5 (59.66) and followed by T_4 (49.68). Whereas the highest reduction was (96.90) recorded from the treatments T_3 which was statistically different from all other treatments. Again the next highest percent of reduction over control was (64.05) calculateded from treatment T_1 which was statistically at par with treatments T_2 and T_5 (63.84 and 57.89), respectively followed by treatment T_4 (53.77).

Table 4.4.60 Effect of different management practices on cotton boll in cotton-rice intercrop field applied against spotted bollworm infestation at Bandarban, Rangamati and Khagrachari during 2016

Treatments	Mean number boll infested boll^{-5} plant^{-1}			Percent reduction infestation of number infested boll^{-5} plant^{-1}		
	Bandar -ban	Ranga -mati	Khagra -chori	Bandar -ban	Ranga -mati	Khagra -chori
T_1 = Spraying Marshal 20EC @ 2 ml Liter^{-1} water at 25 days interval	0.06 b	0.53 c	0.75 c	91.08 a	89.20 a	64.05 b
T_2 = Spraying Actara 25WG @ 0.5 g Liter^{-1} water at 25 days interval	0.02 b	0.72 c	0.74 c	97.47 a	67.69 b	63.84 b
T_3 = Spraying Voliam Flexi 300SC @ 0.5ml Liter^{-1} water at 25 days interval	0.04 b	0.12 d	0.06 d	97.80 a	99.29 a	96.90 a
T_4 = IPM (Nappy+ Hand Weeding+ Spraying Voliam Flexi 300SC @ 0.5 ml Liter^{-1} water apply when necessary)	0.97 a	1.50 b	0.95 b	2.26 b	49.68 c	53.77 c
T_5 = Ripcord 10EC @ 1.0 ml Liter^{-1} water at 25 days interval	0.05 b	1.43 b	0.87 b	97.44 a	59.66 bc	57.89 bc
T_6 = Untreated control	0.99 a	2.91 a	2.05 a	-	-	-
CV (%)	4.96	11.01	4.55	4.77	6.63	4.59

Data are the average of ten observations from 4 replications.
In a column, means followed by same letter(s) are not significantly different by Tukey's HSD test at *$P<0.05$*

4.6.1.6 Effect of different management practices applied against different insect mite pests on seed cotton yield in rice-cotton intercropping in hill districts at CHT of Bangladesh

In 2015, yield result displayed that considerable deviation observed among the management practices in rice-cotton intercrop in respect of seed cotton yield ton ha^{-1}(Table 4.4.61).

Data uncovered that all the plots treated with different treatments were significantly higher than the untreated control plot in both 2015 and 2016. Marketable seed cotton yield ton ha^{-1}and percent of yield over untreated control in different treatments at experimental plots of Bandarban, Rangamati and Khagrachari districts are presented in Table (4.4.61 and 4.4.62). In jhum rice-cotton intercrop experimental fields of 2015, confirmed that the highest yield (2.75 ton ha^{-1}) were recorded from T_3 (spraying Voliam Flexi 300SC @ 0.5ml Liter^{-1} water at 25 days interval) treated plot at Bandarban which was significantly different from T_1 (Farmers practice) and untreated control except statistically at par with treatment T_2 (spraying Actara 25WG @ 0.5 g Liter^{-1} water at 25 days interval) and treatment (T_4), IPM (Nappy+ Hand Weeding+ Spraying Voliam Flexi 300SC @ 0.5 ml Liter^{-1} water apply when necessary). The highest seed cotton yield was 2.73 ton ha^{-1} recorded from treatment T_3 and followed by T_2 and T_4 (2.61 and 2.37 ton ha^{-1}, respectively). However, lowest seed cotton yield was 2.02 and 2.01 ton ha^{-1} at Bandarban and Khagrachari, respectively but they were not significantly different from T_1 (farmers practice) and only provided yield 2.07 and 2.04 ton ha^{-1}, respectively. Among the different treatments at Khagrachari and Bandarban numerically better seed cotton yield obtained from Bandarban experimental fields. Again T_3 provided the highest 2.62 ton ha^{-1} seed cotton yield at Rangamati which was statistically identical with the yield of 2.51 ton ha^{-1} obtained from treatment T_2 (Spraying Actara 25WG @ 0.5 g Liter^{-1} water at 25 days interval) and followed by treatment T_4 (2.27 ton ha^{-1}) but statistically different from the other treatments.

Table 4.4.61 Effect of different management practices applied against different insect mite pests on seed cotton yield in intercrop field at Bandarban, Rangamati and Khagrachari during 2015

Treatments	Marketable yield of cotton ton ha^{-1}			Percent increase of yield over control		
	Bandar-ban	Ranga-mati	Khagra-chori	Bandar-ban	Ranga-mati	Khagra-chori
T_1 = Farmers practice	2.07 b	1.98 cd	2.04 b	2.16 d	4.31 d	2.18 d
T_2 = Spraying Actara 25 WG @ 0.5 g Liter^{-1} water at 25 days interval	2.63 a	2.51 ab	2.61a	30.02 b	31.99 b	30.34 b
T_3 = Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water at 25 days interval	2.75 a	2.62 a	2.73 a	35.92 a	38.28 a	36.30 a
T_4 = IPM (Nappy+ Hand Weeding+ Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water apply when necessary)	2.39 ab	2.27 bc	2.37 ab	18.39 c	19.60 c	18.58 c
T_5 = Untreated control	2.02 b	1.88 d	2.01 b	-	-	-
CV (%)	8.00	6.84	10.42	8.20	11.29	8.53

Data are the average of ten observations from 4 replications.
In a column, means followed by same letter(s) are not significantly different by Tukey's HSD test at $P<0.05$

Untreated control plots at all experimental fields of three hill districts produced the lowest (1.88, 2.01, 2.02 ton ha^{-1}) seed cotton yield due to comparatively higher leaf feeding by bollworm, sucking and insect mite pests infestation thus the lower number of boll set and healthy seed cotton yield was comparatively lower than the other treated plots at Rangamati, Khagrachari and Bandarban. Result also revealed that treatments T_1 (Farmers practice) did not performed well in consideration of rice grain yield compared to other treatments. Jhumian people might adopt other chemical management tools instead of their old aged traditional practices.

In 2015, different chemicals and IPM treatments resulted percent of yield increase over untreated control were recorded as 2.16 -38.28 which were significantly increase the yield over untreated control. Though insect pests infestation comparatively lower in jhum intercrop fields than the hill valley. The order of effectiveness of four treatments over untreated control was T3>T2>T4>T_1≥ T5.

In jhum rice-cotton intercrop experimental fields during the second year (2016) established that the highest yield (2.93 ton ha^{-1}) were recorded from T_3 (spraying Voliam Flexi 300 SC @ 0.5 ml $Liter^{-1}$ water at 25 days interval) at Bandarban which was a significant different from T_4 *i.e.*, IPM (Nappy+ Hand Weeding+ Spraying Voliam Flexi 300 SC @ 0.5 ml $Liter^{-1}$ water apply when necessary) and untreated control but statistically at par with all chemical treatments. The second highest seed cotton yield was (2.81 ton ha^{-1}) from the treatment T_2 and followed by treatments T_2, T_5 and T_4 provided cotton yield of 2.69, 2.67 and 2.58 ton ha^{-1} respectively. At Khagrachari numerically the highest yield was (2.83 ton ha^{-1}) was again produced from T_3 which was statistically at par with all treatment but significantly different from untreated control. Once more treatment T_3 produced the highest (2.73 ton ha^{-1}) seed cotton yield at Rangamati which was statistically identical with yield (2.61 ton ha^{-1}) from treatment T_2 (Spraying Actara 25 WG @ 0.5 g $Liter^{-1}$ water at 25 days interval) but statistically different from other treatments. The second-highest seed cotton yield was recorded from treatment T_2 and followed by treatments T_1, T_5 and T_4 and provided seed cotton yield of 2.49, 2.47 and 2.39 ton ha^{-1} but these yields were significantly different from untreated control. Untreated control plots at all experimental fields of three hill districts provided the lowest (2.20, 2.07, 2.01 ton ha^{-1}) seed cotton yield due to comparatively higher leaf feeding by bollworm, sucking insect and mite pests infestation thus a lower number of boll set and healthy seed cotton yield was comparatively lower than the other treated plots at Bandarban, Khagrachari and Rangamati. The result revealed that treatment IPM (T_4) did not perform satisfactorily in comparison with other chemical treatments to suppress the insect pests to ensure yield increase over untreated control. Boll worm infestation was not enough for visible damage to reduce yield of cotton in the IPM experimental plots but other leaf-feeding and sucking insect infestation were higher but ignored by the Jhumian people which resulted consequently lower yield of seed cotton.

In 2016, different chemicals and IPM treatments ensure percent yield increase over untreated control and were ranged from 16.92 -36.29. The order of effectiveness of five treatments over untreated control was T_3>T_2>T_1>T_5>T_4. On the other hand numerically lower yield of cotton produced from the experimental fields of Rangamati than the other two districts in both 2015 and 2016.

Table 4.4.62 Effect of different management practices applied against different insect mite pests on seed cotton yield in intercrop field at Bandarban, Rangamati and Khagrachari during 2016

Treatments	Marketable yield of seed cotton ton ha^{-1}			Percent increase of yield over control		
	Bandar-ban	Ranga-mati	Khagra-chori	Bandar-ban	Ranga-mati	Khagra-chori
T_1 = Spraying Marshal 20 EC @ 2 ml $Liter^{-1}$ water at 25 days interval	2.69 ab	2.49 b	2.59 a	22.03 c	24.19 c	23.06 c
T_2 = Spraying Actara 25 WG @ 0.5 gm $Liter^{-1}$ water at 25 days interval	2.81 ab	2.61 ab	2.71 a	27.62 b	30.33 b	28.92 b
T_3 = Spraying Voliam Flexi 300 SC @ 0.5 ml $Liter^{-1}$ water at 25 days interval	2.93 a	2.73 a	2.83 a	33.05 a	36.29 a	34.60 a
T_4 = IPM (Nappy+ Hand Weeding+ Spraying Voliam Flexi 300 SC @ 0.5 ml $Liter^{-1}$ water apply when necessary)	2.58 b	2.39 b	2.48 ab	16.92 d	18.58 d	17.71 d
T_5 = Ripcord 10 EC @ 1.0 ml $Liter^{-1}$ water at 25 days interval	2.67 ab	2.47 b	2.57 a	21.16 c	23.24 c	22.16 c
T_6 = Untreated control	2.20 c	2.01 c	2.07 b	-	-	-
CV (%)	5.52	4.21	7.71	7.43	7.78	7.07

Data are the average of ten observations from 4 replications.

In a column, means followed by same letter(s) are not significantly different by Tukey's HSD test at $P<0.05$

CHAPTER V

SUMMARY

The study comprised four experiments carried-out during the jhum season from April 2014 to January 2016 at different locations of Khagrachari, Rangamati and Bandarban districts which included (1) survey on insect and mite pests of the existing cropping system and farmer's practices, (ii) Identification of common insect mite pests found in jhum and rice-cotton intercropping system, (iii) study on the population dynamics and extent of damage of major and auspicious insect pests, (iv) study to develop pest management approaches for jhum and rice-cotton intercropping system at hill region of (Chattogram Hill Tracts) of Bangladesh.

The first experiment was a survey conducted during the month of March 2014 to January 2015 in Bandarban, Rangamati and Khagrachari hill districts of the CHT areas of Bangladesh to know the insect and mite pest incidence, farmers' practices (FPs), Jhum farming experience and effectiveness of chemicals in managing its major insect pests.

Randomly selected a total of 150 farmers, @ 50 farmers per hill district were interviewed through structured questionnaire used to collect relevant data. A total of 125 plots were visited. Among the sample of 150 farmers, 66.67% had experience in jhum farming whereas rest 33.33% did not have any experience with jhum farming. While On an average, 19.33% of sample farmers received pest management and other training whereas, 80.67% did not receive any types of training. Jhumian farmers were familiar with their traditional pest management system to suppress the insect pests and others.

Among the 11 species on cotton and five species on rice, red cotton bug, cotton jassid and leaf roller and rice bug, rice leaf roller/folder, rice grasshopper, rice yellow stem borer and rice green leafhopper are nominated as major insect pests as their infestation were prominent and easily visible by Jhumian people while others were considered as minor insect pests.

The second experiment was conducted in the Seingulipara, Guimara upazila, Khagrachari district; Shapchari, Rangamati district; Tigerpara, Bandarban Sadar of the CHT during April 2014 January 2015 to validate on-farm/field of the insect pests status found in jhum and rice-cotton intercropping system. Forty-eight (48) insect mite pests were found to the selected rice jhum and intercrop experimental fields.

Hill Sesame plant serves as a host belong to seven arthropod orders recorded 30 insect mites' species. Leaf webber insect revealed mean infestation were 12.63%, 11.28% and 18.59%, whereas different phloem-feeders bugs combined caused 9.73%, 13.72% and 11.33% of infestation in that order and considered as major insect pests.

Although country bean recorded 22 insect mites species among them only three species of bean pod borer, black bean aphid considered as major insect pests. Cowpea and yard-long bean (17 and 16) insect mites species respectively were recorded but bean pod borer and bean aphid (*Aphis craccivora* (Kosh)) established major pests affected (19.34%, 17.06% and 21.34%) and (15.75%, 18.23% and 12.97%) individually.

Hill squash *i.e.* marpha served as host belong to seven arthropod orders recorded 18 insect mites species among them two families, two fruit flies combine infestation were (Bandarban 33.10%) (Rangamati 35.37%) and (Khagrachari 26.57%) during the fruiting period and undoubtedly established major insects while phloem feeders different stink bug (9.73 to 12.91%), aphid and jassid caused up to (7.32 to 7.22%) of infestation of foliage and others did as minor insects. Okra plant serve the host of 13 insect mites species among two species aphid and jassid revealed mean percentage of infestation were up to (30.59% and 30.84%) respectively triggered the highest level of infestation and designated major insect pests, while okra shoot and fruit borer caused insignificant infestation (2.47%) at jhum field with other 10 species nominated as minor pests.

Among 24 species of insect mite pests of eggplant, brinjal shoot and fruit borer (BSFB) caused maximum damage during the fruiting period were (32.17% at Bandarban) (35.98% at Rangamati) and (29.37% at Khagrachari) and epilachna beetle badly damage in the early stage of brinjal plant by feeding the leaves and their mean percentage of infestation were (Bandarban 12.56, Rangamati 14.07 and Khagrachari 10.56) both considered as major insect pests while others remark as minor pests.

Insect and mites belong to six arthropod orders recorded eleven (11) insect mites species on hill chili (bindu morich) belonging to the orders Hemiptera, Lepidoptera, Coleoptera, Isoptera, Thysanoptera and mites have its a place in the order Acarina which species chili mite and their mean percentage of infestation were (Bandarban 25.82, Rangamati 16.06 and Khagrachari 23.34). Whereas thrips revealed infestation were (15.03%, 17.84% and 21.17%) devastating role during early stage of chili plants and both reflected as major insect mite pests. Chili fruit borer or gram caterpillar instigated the maximum damage (6.07%) during the fruiting period caused moderate level infestation thus need to care about their future intensity of attack as promising insect but others were low infestation and measured as minor pests.

Among 12 species of insect mite pests of maize, four insect taxa of different grasshoppers comprise the only family of Acrididae were particularly foliage feeder during the vegetative period and their combined infestation were (67.71%, 65.07% and 74.44%) painstaking as major insect pests. Rest of 8 species not damaged significantly on maize thus nominated as minor insect pests. From our survey report as of different Jhumian people, they are very worried about a wild pig, monkey, squirrel on maize field and different cob eating birds were remarkable damage were normal feature at jhum fields as well as in the valley of CHT of Bangladesh.

The cotton plant serves as a host for an extensive range of insect orders. Many foliage feeding, stem feeding, fruit fly and leaf minor insect mites belong to seven arthropod orders recorded 45 insect mites species. Insects belonging to the orders Orthoptera, Lepidoptera, Hemiptera, Coleoptera, Isoptera and mites. Among them phloem-feeders (2 species of aphid, jassid and one species of whitefly) within the order of Hemiptera on cotton crop originated maximum damage (22.45%, 19.03% and 9.77% to 23.13%) respectively.

Among the different insect and mite taxa on chili, broad mite badly damage throughout jhum season of chili plant and their rate of infestation were Bandarban 25.82%, Rangamati 16.06% and Khagrachari 23.34% caused the uppermost level of infestation and considered as major mite pests. Furthermore other one taxa rasping and sucking (thrips) of order Thysanopteran include Thripidae family revealed their rate of infestation as Bandarban 15.03%, Rangamati 17.84% and Khagrachari 21.17% showed the second highest infestation and considered as major insect pest.

Maximum 4 insect taxa of different grasshopper were recorded from important insect order. Orthoptera comprise the only family of Acrididae represented are particularly foliage feeder on maize plant at jhum field and caused maximum damage during the vegetative period and their rate of infestation were Bandarban 67.71%, Rangamati 65.07% and Khagrachari 74.44% which showed the uppermost level thus their combined destruction considered as major insect pests.

Among ten insect's taxa on cotton two species of aphid caused the infestation rate of 15.67% at Bandarban, 22.45% at Rangamati and 19.67% at Khagrachari, whereas jassid and Indian cotton jassid caused the infestation rate of 16.45% at Bandarban, 18.05% at Rangamati and 19.03% at Khagrachari. Another sucking insect *i.e.*, whitefly has similar trend of percent of infestation and were Bandarban 9.77%, Rangamati 23.13% and Khagrachari 6.76% and these phloem-feeders caused moderate to high level of infestation and considered as major insect pests.

The third experiment was conducted in a randomized complete block design (RCBD) from farmer's field of jhum and rice-cotton intercropping during the months of April 2015 to January 2016 at different locations of Bandarban, Rangamati and Khagrachari districts under the field conditions to know the seasonal influence on the incidence and abundance and to determine the extent of damage of different insect pests found in jhum and rice-cotton intercropping system.

With increasing of rainfall and temperature, the population of aphid, jassid, whitefly and thrips leaf^{-1} on chili, suddenly decreased up to 1st week of July and slightly increased, and remain more or less fixed number up to 1st week of August at all experimental regions of hilly districts. With the decreasing of rainfall, the population of aphid and jassid leaf^{-1} increased gradually and reached a peak on end of September. Thrips infestation gradually increased and reached the highest number of thrips leaf^{-1} at mid-September and remain their incidence at the end of jhum season. While low temperature and no rainfall, number of whitefly increased and reached the highest at October. However the chili fruit borer infestation were less than the sucking pests on green chili and confined their incidence during the later stage of crop.

With decreased mean rainfall, percentage of fruit fly-infested fruit plant^{-1} on marpha was the highest during the initial infestation when the number of fruits are few at all experimental fields then infestation slightly declined up to the 3rd week of August and subsequently the infestation was slowly increased at the later stage of the crop. Red pumpkin beetle-infested leaves plant^{-1} started from seedling stage in the jhum fields and percent of infestation abruptly amplified and reached the maximum during the end of June and early July. Percent infestation of **s**ap sucking insect pests of jassid, aphid and pentatomid bug on marpha leaves were sharply increased and reached a maximum the end of June and early July then incidence of infestation harshly declined at all the three hill districts at the end of August to September.

While epilachna beetle infestation were increasing and reached a maximum at the end of July and *w*ith the decreased mean rainfall and temperature, infestation declined ascetically up to the 3rd week of August. Leaf minor infestation on leaves plant^{-1} were started at an early stage of the crop during the period of 2nd week of July and disappeared at early August.

Aphid and jassid on okra leaf^{-1} was gradually increased and reached the maximum for the period after mid-week of July with decreasing mean rainfall and increasing relative humidity again the infestation slightly decreased with reduced mean rainfall and temperature at the end of September. While, whitefly infestation start after early July, it gradually increased their incidence and reached the maximum during the end of September and early October. The major insect pest of okra shoot and fruit borer infested fruits plant^{-1} and reached the maximum during October and declined gently at the later stage of the jhum season.

Aphid infested on sesame twigs plant^{-1} also fluctuate with environmental factors. With decreasing rainfall and temperature infestation increased very slowly and reached the maximum of 17.44, 12.96 and 8.93 at the end of the crop when pod mature enough for harvest similar incidence were observed in Jassid infestation and increased and grasped the maximum mid-November.

Major insect of sesame, leaf webber infestation start July, with increasing temperature percent infestation sharply increased and reached the peak during the early September. Their intensity of infestation suddenly declined and the caterpillar disappeared approximately 4th week of September with decreasing mean rainfall and temperature.

Percent of infestation of flea beetle severely increased and reached the maximum of 9.67, 7.68 and 16.99 during early September. After the end of October, the percent infestation abruptly declined due to mature stage of sesame plant and declined the temperature and rainfall.

Though the pod borer infestation was not significant and confined in their infestation only pods in between one month of infesting and reached the highest during the end of October. While the major insect pentatomid bug-infested leaves plant^{-1} started very slowly at the 1st week of July and progressively increased and reached a maximum at the end of August.

Percentage of grasshopper infestation start at July and maintain their devastation and reached a maximum level of 74.93 and 71.16 during the end of 3rd and 4th week of August, then the infestation decreased with maturity of maize leaves and disappeared after the beginning month of September.

Rice in jhum and intercrop rice-cotton field grasshopper infestation on rice started during 1st week of June and reached the maximum during the end of July. After peak percent infestation slightly declined and its damage to the leaves continued till 1st week of September. While rice bug infestation was started with decreasing mean rainfall and temperature, preliminary insignificant infestation amplified throughout the panicle initiation stage and reached the maximum at the end of September.

Rice leaf folder infestation started during the July and gradually increased reached a maximum during the end of August and 1st week of September. After initial infestation at July, percentage of flea beetle infestation gradually increased with an increasing number of tillering of the intercrop rice and reached the maximum during the end of August, then the infestation intensity declined and flea beetle disappeared after mid-September. But the intensity of attack during 2016 were comparatively higher than the year 2015.

Rice stem borer infestation started in the month of June and with the increasing number of tiller, percent infestation of stem borer progressively increased and reached a maximum before the harvesting i.e., at end of the month of September. Very insignificant termite infestation occur for short duration after rive seedling arise and nonappearance after the month of July.

The fourth experiment was conducted in a randomized complete block design (RCBD) in this from farmer's field of jhum and rice-cotton intercropping during the month of April 2015 to January 2016 at different locations of Bandarban, Rangamati and Khagrachari districts to evaluate the efficacy of some practices and find out suitable one (s).

The highest rate of reduction of infestation of fruit borer infested chili fruit plant^{-1} over control was recorded from treatment T_3 (49.28) which was at par to that of treatment T_2 (43.05), followed by T_1 (36.04) and T_5 (34.89) at Bandarban. The highest rate of reduction of infested fruit per plant^{-1} over control was recorded from treatment T_3 (50.81) which significantly different from all other treatments and followed by T_5 (35.30), T_1 (36.12), T_2 (41.55), T_4 (20.09) at Bandarban.

Result specified that marketable green chili yield (2016) at the experimental field of Bandarban was the highest (199.67 g plant^{-1}) from the treatment T_3 (spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water at 25 days interval), which was statistically different from all other treatments. The second highest yield (184.48 g plant^{-1}) was recorded from treatment T_2 (spraying Actara 25 WG @ 0.5 g Liter^{-1} water at 25 days interval) which was statistically identical to that of T_1 (spraying Marshal 20 EC @ 2 ml Liter^{-1} water at 25 days interval) and was followed by T_5 (Ripcord 10 EC @ 1.0 ml Liter^{-1} water at 25 days interval) and T_4 *i.e.*, IPM (Nappytrap+ Hand Weeding+ Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water apply when necessary). The order of effectiveness of five treatments over untreated control was $T_3>T_2>T_1>T_4>T_5$.

The reduction of infested maize leaves plant^{-1} over control ranged from (25.73 -37.28), (21.03 -32.93) and (19.15 -38.16) during the whole vegetative till the beginning of cob forming period representing the satisfactory protection from grasshopper at Bandarban, Rangamati and Khagrachari respectively. The highest rate of reduction of infested leaves plant^{-1} over control was recorded from treatment T_5 (37.28) which was at per but numerically lower with treatment T_2 (31.93) but significantly different from treatments T_3 (28.71), T_4 (28.47) and T_1 (25.73) at Bandarban.

Considerable variations among the management practices in respect of maize seed yield and result indicated that all chemical and IPM practices provided marketable maize seed yield at experimental field except untreated control and farmers practices. But maize plant and the cob were sometimes harshly damaged by Fox and cob eating birds. Study considered only insect and mite as pests'.

The reduction of total infested marpha fruits plan^{-1} over control ranged from (23.62 -35.70), (13.47 -41.68) and (18.48 -36.75) during the entire fruiting period indicating the predictable protection from marpha fruit borer at Bandarban, Rangamati and Khagrachari, congruently. The lowest (16.34) percent of infestation was observed from treatment T_3 which was at par but numerically to some extent higher infestation from the treatments T_2 (19.75) followed by T_1 (20.67), T_5 (21.62) and T_4 (21.67), at Khagrachari. Marketable marpha fruit yield at the experimental field of Khagrachari was highest (1.31 kg plant^{-1}) and was recorded from treatment T_3 (spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water at 25 days interval) treated plot which was statistically identical with that of treatments T_2 and T_1 but statistically different from other treatments. During the year 2016 different chemicals and IPM treatments result an adequate yield increase over untreated control and was ranged from (7.10 -21.36 kg plant^{-1}). The order of effectiveness of four practices over untreated control were T_3>T_2>T_1>T_4>T_5.

The reduction of percent infested okra fruits plant^{-1} over control was ranged from 7.70 -31.65, 9.99 -42.11 and 13.83 -41.12 during the entire fruiting period indicating the projected protection from okra shoot and fruit borer at Bandarban, Rangamati and Khagrachari respectively. The highest percent of reduction of infested fruit plant^{-1} over control was achieved from treatment T_3 (31.65) which was statistically different from all other treatments at Bandarban. At Bandarban, the lowest percent of aphid infested okra leaves plant^{-1} was recorded (15.38) from treatment T_3 which was statistically equivalent with treatments T_4, T_1 and T_2 (16.06, 16.92 and 18.42 respectively). The reduction of total infested leaves plant^{-1} over control ranged from (34.14 -53.88), (18.60 -49.54) and (46.59 -73.97) during the entire fruiting period indicating the substantial protection from aphid at Bandarban, Rangamati and Khagrachari, correspondingly.

The highest percentage of reduction of infested jassid leaves plant^{-1} over control was recorded from treatment T_3 (68.22) which was significantly different from all other treatments at Khagrachari. At Bandarban, the highest whitefly infestation reduction over control was observed from treatment T_5 (91.89) which was statistically similar with treatments T_3, T_1 and T_2. In the year 2016, different chemicals and IPM treatments the percent yield increase over untreated control were ranged from (11.58 -41.54 kg plant^{-1}) which were satisfactory increase. The order of effectiveness of four treatments over untreated control were T_3>T_5>T_2>T_1>T_4.

The reduction of sesame leaf webber infested leaves plant^{-1} over control ranged from (7.47 -30.68), (4.53 -40.53) and (27.27 -55.75) during the cropping period at Bandarban, Rangamati and Khagrachari, correspondingly. However, at Khagrachari the uppermost decrease was observed from treatment T_2 (55.75) which was statistically similar to that of treatments T_1 and T_3 and followed by T_4. The reduction of total infested pods branch^{-1} plant^{-1}over control ranged from (32.14 -94.68), (36.14 -92.16) and (26.54 -85.96) during the entire pod setting to pod maturing stage indicating the substantial protection from pod borer caterpillar at Bandarban, Rangamati and Khagrachari, respectively. The highest rate of reduction of infestation of pods branch^{-1} plant^{-1}over control was recorded from treatment T_5 (94.68) which was statistically different from all other treatments at Bandarban. The second highest infestation reduction over control was observed from treatment T_3 (82.22) which was statistically similar to that of treatments T_4 and followed by T_1 and T_2. In 2016 different chemicals and IPM treatments provided percent of yield increase over untreated control were ranged from recorded 1.44 -6.32 g plant^{-1}. The order of effectiveness of four treatments over untreated control were $T_3>T_2>T_1>T_5>T_4$ indicated that the chemical treatments at the mature stage of sesame plant performed better than the farmer's practice.

The highest rate of reduction of rice bug infested grain plant^{-1} over control was recorded at jhum rice during 2015 from treatment T_3 (70.97, 79.54 and 93.36) at Bandarban, Rangamati and Khagrachari, correspondingly and these were statistically different from all other treatments of the experimental fields of three hill districts and followed by treatments T_2 (56.93, 63.86 and 74.94), T_4 (18.33, 20.58 and 24.16). The reduction of infested stem hill^{-1} over control ranged from (42.01 -48.72), (35.38 - 62.91) and (58.12 -79.43) before panicle initiation till harvesting of rice crop indicating the considerable protection from rice stem borer at Bandarban, Rangamati and Khagrachari, correspondingly. The highest rate of reduction of infested stem hill^{-1} over control was documented from treatment T_3 (79.43) at Khagrachari which was statistically at par with treatments T_2, and different from other treatments. The highest percent reduction of infestation of grasshoppers infested leaves hill^{-1} over control was recorded from treatment T_3 (76.25) at Khagrachari which was significantly at par with treatments T_1, but different from other treatments. The second maximum reduction was (70.02) observed from treatment T_1 but significantly at par with treatment T_2 (63.94) and followed by treatment T_4 (56.60). The highest percent reduction of leaf folder infested leaves hill^{-1} over control was recorded from treatment T_3 (78.07, 81.30 and 46.06) at Bandarban, Rangamati and Khagrachari respectively and those were statistically different from all other treatments accept similar to that of treatments T_2 (65.99 and 37.39) at Rangamati and Khagrachari, respectively. The highest percent reduction of flea beetle-infested leaves hill^{-1} over control was recorded from treatment T_5 (91.03 and 38.13) and those were statistically at par with treatment T_3 (90.09 and 37.87) at Khagrachari and Rangamati, respectively but significantly different from all other treatments. In rice-cotton intercropping system indicating similar result as jhum system and the considerable protection and provided significant yield increased over untreated control from different insect pests of rice at Bandarban, Rangamati and Khagrachari, respectively. In 2016 different chemicals and IPM provided percent yield increase over untreated control were ranged from 28.99 -91.77 at jhum system. The order of effectiveness of five treatments over untreated control were $T_3>T_2>T_1>T_5>T_4$.

In 2015 different chemicals and IPM treatments percent of yield increase over untreated control was ranged from (2.25 -76.33) at intercrop system. Though insect pest infestation comparatively lower at jhum intercrop fields than the hill valley, the order of effectiveness of four treatments over untreated control was $T_3>T_2>T_4>T_1\geq T_5$. In 2016 different chemicals and IPM treatment plots showed percent yield increase over untreated control ranged from 22.51 -78.42. The order of effectiveness of five treatments over untreated control was $T_3>T_2>T_1>T_5>T_4$. Result revealed that rice-cotton intercrop provided higher rice grain yield than normal jhum cultivation at all three hill districts experimental fields.

In 2015, the reduction of the percent of infested leaves plant^{-1} over control was ranged from (16.45-55.19), (11.35 -78.87) and (15.50 -50.24) during the vegetative till to boll maturing period, indicating the considerable protection from aphid at Bandarban, Rangamati and Khagrachari, respectively. Whereas the highest and the second highest reduction (73.97 and 60.59) were recorded from the treatments T_3 and T_2, respectively and they were statistically different from each other from all other treatments at Khagrachari. The lowest percent of jassid infested leaves plant^{-1} was recorded (2.04, 3.55 and 3.38) from treatment T_3 which were statistically similar to that of treatment T_2 (2.59, 4.07 and 3.94) at Bandarban, Rangamati and Khagrachari, respectively during 2015.

In 2016, the reduction of total infested leaves plant^{-1} over control was ranged from (35.95 -53.50), (16.70 -50.28) and (46.59 -73.97) at vegetative stage till the boll maturing stage of intercrop cotton indicating the substantial protection from jassid at Bandarban, Rangamati and Khagrachari, respectively.

In 2015, the highest rate of reduction of whitefly infestation over control was (40.52, 67.80 and 58.50) recorded from treatment T_3 which were statistically different from other treatments at Bandarban, Rangamati and Khagrachari, respectively. Whitefly infestation was very low in comparison to previous year 2015, whereas the highest, second and third highest reduction (77.65, 75.85, and 73.80) were revealed from the treatments T_2, T_1 and T_3, respectively.

The percent infested boll plant^{-1} were ranged from (13.70-32.94), (22.46 -48.17) and (15.99 -31.15) at the boll setting stage till the boll maturing stage of intercrop cotton at Bandarban, Rangamati and Khagrachari, respectively. The highest percent of reduction of red cotton bug staining boll plant^{-1} over control was recorded from treatment T_3 (53.38) which was significantly different from all other treatments at Rangamati. At Bandarban the lowest number infested boll^{-5} plant^{-1}was recorded (0.02) from treatment T_2 which was statistically similar to that of treatments T_3, T_5, and T_1 (0.04, 0.05 and 0.06), respectively and different from treatments T_4 (0.32) and untreated control during 2016. In 2015, different chemicals and IPM treatments resulted percent of yield increase over untreated control were recorded as 2.16 -38.28 which were significantly increase the yield over untreated control. Though insect pests' infestation comparatively lower in jhum intercrop fields than the hill valley. The order of effectiveness of four treatments over untreated control was $T_3>T_2>T_4>T_1\geq T_5$.

In jhum rice-cotton intercrop experimental fields during the second year (2016) established that the highest yield (2.93 ton ha^{-1}) were recorded from T_3 (spraying Voliam Flexi 300 SC @ 0.5 ml $Liter^{-1}$ water at 25 days interval) at Bandarban which was a significant different from T_4 i.e., IPM (Nappy+ Hand Weeding+ Spraying Voliam Flexi 300 SC @ 0.5 ml $Liter^{-1}$ water apply when necessary) and untreated control but statistically at par with all chemical treatments. The second highest seed cotton yield was (2.81 ton ha^{-1}) from the treatment T_2 and followed by treatments T_2, T_5 and T_4 provided cotton yield of 2.69, 2.67 and 2.58 ton ha^{-1} respectively. In 2016, different chemicals and IPM treatments ensure percent yield increase over untreated control and were ranged from 16.92-36.29. The order of effectiveness of five treatments over untreated control was $T_3>T_2>T_1>T_5>T_4$.

CHAPTER VI

CONCLUSION

Based on findings of the present study the following conclusions may be drawn:

- Among the sample (150) farmers, 66.67% have experience with jhum farming whereas rest 33.33% farmers were not familiar with their traditional pest management practices.
- Almost average, 19.33% of sample farmers received pest management and other training although maximum (80.67%) of this did not receive any types of training.
- Diversity of insect & mite pests of jhum and hill rice-cotton intercrop were identified. The infestation by the major and promising insect & mite pests and their abundance, seasonal incidence and extent of damage of jhum and hill rice-cotton intercrop were studied and found significantly varied with temperature, rainfall and humidity.
- The results reaveled that different phloem-feeders bugs, aphid, jassid, whitefly, different hoppers, mites, flea beetle, fruit fly, OSFB, BSFB, pod borer, leaf webber caterpillar, different grass hopper, leaf folder, red cotton bug, rice bug causes significant damage to jhum crops as well as rice-cotton intercrop in hill districts.
- Farmer's practices (T_1) of Jhumian people was less effective to suppress insect and mite pests predominant on hill districts.
- IPM package *i.e.* T_4 (Nappy trap+ Hand Weeding+ Spraying Voliam Flexi 300 SC @ 0.5 ml Liter^{-1} water apply when necessary) failed to achieve economic suppression of insect and mite pests compared to other chemicals probably due to monsoon rainfall and inexperience about the promising insect pests. Jhumian farmers are reluctant to use hand weeding and need based spraying of Voliam Flexi 300 SC on their selected plots.
- Considering the reduced rate of infestation the highest reduction of infestation over control, achievement of higher yield among the tested management options, the option T_3 (spraying Voliam Flexi 300SC @ 0.5 ml Liter^{-1} water at 25 days interval) was most effective to suppress insect and mite pests in jhum and rice-cotton intercropping system in the hill tracts of Bangladesh.

RECOMMENDATIONS

- Natural Enemies observed in jhum and hill rice-cotton intercrop in the present study the contribution in natural insect pest suppression may be evaluated in details for inclusion as bio-control agents in the IPM package.
- The package integrating chemical and non-chemical components with upgrading traditional practice may be evaluated for large scale under farmer's field conditions in different jhum, monoculture and intercrops in hill districts of Bangladesh.
- Survey in the present study reaveled that 80.67% of the hill farmers didn't received any kind of training. Only 19.33% of hill farmers received training on insect pest management and others training. Concerned authorities particularly DAE should take necessary measuresto provide training on IPM, utililizing biocontrol agents, biopesticides and others ecofriendly management options.

CHAPTER VII

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APPENDICES

Appendix 8.1 Mean weather data from May to December at Bandarban during 2015 and 2016

Date, Month	During 2015 at Bandarban			During 2016 Bandarban		
	Mean Rainfall (mm)	Mean Temperature (°C)	Mean RH (%)	Mean Rainfall (mm)	Mean Temperature (°C)	Mean RH (%)
09, May	2.20	29.55	85.87	1.13	30.68	83.47
23, May	2.56	29.23	85.06	11.29	29.23	87.71
09, June	12.24	29.39	86.71	29.27	32.75	89.20
23, June	48.33	27.11	89.07	16.33	24.77	89.60
09, July	15.40	28.83	88.93	24.07	28.10	90.20
23, July	47.94	26.06	90.25	10.69	27.50	89.38
09, Aug	16.33	28.37	89.47	19.33	28.13	89.73
23, Aug	30.16	27.66	91.25	11.13	28.58	90.38
09, Sep	19.43	28.46	91.29	22.27	28.36	83.58
23, Sep	6.93	28.44	86.87	11.13	28.57	84.58
09, Oct	20.87	27.62	88.20	11.41	28.21	85.81
23, Oct	0.00	27.57	83.67	5.71	28.42	83.81
09, Nov	0.21	25.61	83.00	7.55	23.07	80.09
23, Nov	0.27	24.62	82.93	3.78	23.27	81.09
09, Dec	0.00	23.12	81.13	0.00	20.64	79.80
23, Dec	0.63	19.93	83.25	0.00	20.85	80.80

Source: Soil Resource Development Institute, Bandarban and Bangladesh Metrological department, Agargaon, Dhaka

Appendix 8.2 Mean weather data from May to December at Rangamati during 2015 and 2016

Date, Month	During 2015 at Rangamati			During 2016 Rangamati		
	Mean Rainfall (mm)	Mean Temperature (°C)	Mean RH (%)	Mean Rainfall (mm)	Mean Temperature (°C)	Mean RH (%)
05, May	0.53	27.89	78.27	3.27	28.48	72.80
20, May	6.00	28.89	78.44	12.38	27.81	80.88
05, June	10.40	28.48	80.07	25.07	27.14	79.87
20, June	29.47	27.44	85.67	10.60	28.64	74.87
05, July	17.47	27.75	84.13	19.20	27.74	78.20
20, July	50.88	26.31	91.69	6.88	27.19	82.88
05, Aug	16.20	28.15	83.13	11.27	27.70	81.73
20, Aug	32.81	27.23	88.06	8.81	28.17	85.06
05, Sep	14.80	27.89	85.27	6.87	27.85	83.93
20-Sep	6.13	28.01	81.67	4.40	27.90	83.07
05, Oct	9.27	26.71	84.00	3.67	27.42	83.73
20, Oct	0.94	26.28	84.38	1.75	27.21	81.06
05, Nov	0.13	23.72	82.93	8.00	24.43	83.67
20, Nov	0.53	22.55	82.33	0.00	21.16	78.13
05, Dec	0.00	20.85	83.67	0.00	21.17	77.13
23, Dec	0.06	17.58	79.56	0.00	20.64	79.94

Source: Bangladesh Metrological department, Agargaon, Dhaka

Appendix 8.3 Mean weather data from May to December at Khagrachari during 2015 and 2016

Date, Month	During 2015 at Khagrachari			During 2016 Khagrachari		
	Mean Rainfall (mm)	Mean Temperature (°C)	Mean RH (%)	Mean Rainfall (mm)	Mean Temperature (°C)	Mean RH (%)
05, May	2.42	28.04	74.93	5.73	27.89	72.67
20, May	8.88	29.84	75.50	20.25	27.04	80.00
05, June	11.94	29.63	78.27	13.97	28.58	84.80
20, June	28.73	28.39	81.73	7.96	29.22	80.53
05, July	20.54	27.01	77.53	17.05	27.22	85.13
20, July	34.84	26.83	88.44	11.51	27.33	84.53
05, Aug	9.60	28.27	82.13	10.20	28.56	83.87
20, Aug	29.56	27.24	83.31	19.22	28.54	84.00
05, Sep	20.89	28.16	82.93	17.70	29.09	81.87
20-Sep	11.80	28.64	75.67	6.08	29.43	78.40
05, Oct	14.12	28.49	80.67	7.95	29.63	81.93
20, Oct	0.47	27.61	77.25	3.43	29.40	76.00
05, Nov	0.00	25.15	74.20	6.47	25.13	79.33
20, Nov	0.00	23.59	77.27	0.00	22.37	75.60
05, Dec	0.00	18.47	83.13	0.00	20.88	73.33
23, Dec	0.00	21.21	79.69	0.00	20.71	79.00

Source: Bangladesh Metrological department, Agargaon, Dhaka and RARS, BARI, Khagrachari

Appendix 8.4 Questionnaire on Jhumian practice and pest management of hill agricultural farming

পাহাড়ী কৃষি ব্যবস্থায় কৃষকের নিজস্ব বালাই ব্যবস্থাপনা প্রশ্নমালা

১। উত্তরদাতার নাম ঃ .... ২। বয়স ঃ...
৩। পিতার নাম ঃ .... ৪। মাতার নাম ঃ ....
৫। ঠিকানা ঃ পাড়া/মহল্লা ঃ .... গ্রাম ঃ .... ডাক ঘর ঃ ....
থানা ঃ .... জেলা ঃ ....
৬। শিক্ষাগত যোগ্যতা (√) ঃ নিরক্ষর/অক্ষরজ্ঞান সম্পন্ন/প্রাইমারী/মাধ্যমিক/ গ্রাজুয়েট/মাস্টার্স
৭। পরিবারের সদস্য সংখ্যা ঃ ক) প্রাপ্ত বয়স্ক .... খ) অপ্রপ্তবয়স্ক............................
৮। জমির পরিমান ঃ ক) বসত বাড়ী .... খ) জুম...................... গ) কৃষি জমি ....
ঘ) ফল বাগান .... ঙ) অন্যান্য ....

৯। চাষাবাদ পরিচিতি ঃ

চাষাবাদের ধরণ	জমির ধরণ	জমির পরিমান	সাথী ফসল	বপন/রোপনের সময়	ফসল কাটার সময়	ফলন	ফসলের ক্ষয়ক্ষতির প্রধান কারন সমূহ
জুম							
পাহাড়-১							
পাহাড়-২							
পাহাড়-৩							
একক/অস্ত ফসল							
১।							
২।							
৩।							
৪।							
শাক-সবজি							
১।							
২।							
৩।							
৪।							
ফল বাগান							
১।							
২।							
৩।							

১০। আগাছা ব্যবস্থাপনা সম্পর্কিত তথ্য ঃ

ফসল	গুরুত্ব অনুযায়ী আগাছার নাম	দমন পদ্ধতি	মন্তব্য
জুম			
পাহাড়-১			
পাহাড়-২			
পাহাড়-৩			
একক/অন্ত ফসল			
১।			
২।			
৩।			
৪।			
শাক-সবজি			
১।			
২।			
৩।			
৪।			
ফল বাগান			
১।			
২।			
৩।			
৪।			

১১। পোকামাকড় ব্যবস্থাপনা সম্পর্কিত তথ্য ঃ

ফসল	গুরুত্ব অনুযায়ী পোকা/মাকড়ের নাম/বিবরণ	লক্ষণ/উপসর্গ	গাছের কোন অংশে বেশী দেখা যায়	দমন পদ্ধতি	মন্তব্য
জুম					
পাহাড়-১					
পাহাড়-২					
পাহাড়-৩					

একক/অন্ত ফসল					
১।					
২।					
৩।					
৪।					
শাক-সবজি					
১।					
২।					
৩।					
৪।					
ফল বাগান					
১।					
২।					
৩।					
৪।					

১২। রোগ বালাই ব্যবস্থাপনা সম্পর্কিত তথ্য ঃ

ফসল	গুরুত্ব অনুযায়ী রোগের নাম/বিবরণ	লক্ষণ/উপসর্গ	গাছের কোন অংশে বেশী দেখা যায়	দমন পদ্ধতি	মন্তব্য
জুম					
পাহাড়-১					
পাহাড়-২					
পাহাড়-৩					
একক/অন্ত ফসল					
১।					
২।					
৩।					
৪।					
শাক-সবজি					
১।					
২।					
৩।					
৪।					
ফল বাগান					
১।					
২।					
৩।					
৪।					

১৩। বালাই নাশক ব্যবহার সম্পর্কিত তথ্য ঃ

বালাই নাশকের ধরন	কেন ফসলে ব্যবহার করেন	কতবার ব্যবহার করেন	কোন মাত্রায় ব্যবহার করেন √)		ব্যবহারকৃত মাত্রা	মন্তব্য
			অনুমোদিত	নিজস্ব অনুমান		
আগাছা নাশক						
১।						
২।						
কীটনাশক						
১।						
২।						
৩।						
৪।						
ছত্রাক নাশক						
১।						
২।						
৩।						

১৪। বালাই সমূহের বালাই নাশক প্রতিরোধ ক্ষমতা সম্পর্কিত তথ্য ঃ

বালাই এর ধরন	বালাই নাশক প্রতিরোধ ক্ষমতা(√)				প্রতিরোধ ক্ষমতা থাকলে বিকল্প দমন পদ্ধতি সমূহ	মন্তব্য
	বেশী	মাঝারী	কম	নেই (দমন হয়)		
আগাছা						
১।						
২।						
৩।						
পোকামাকড়						
১।						
২।						
৩।						
৪।						
রোগবালাই						
১।						
২।						
৩।						

১৫। সনাতন বালাই ব্যবস্থাপনা সম্পর্কিত তথ্য ঃ

বালাই এর ধরন	সনাতন/স্থানীয় দমন পদ্ধতি	কৃষক নিজে ব্যবহার (√)			মন্তব্য
		করেন	মাঝে মধ্যে করেন	করেন না	
আগাছা					
পোকামাকড়					
রোগবালাই					

১৬। কত বছর যাবৎ জুম চাষ
করেন?...

১৭। একই জমিতে জুমের আবর্তন কাল কত বৎসর?

১৮। প্রতি আবর্তনে সাথী ফসল পরিবর্তন হয় কি না? (√) দিন হাঁ/ না/ মাঝে মধ্যে

১৯। ফসল পরিবর্তনের কারনসমূহ কি কি?

২০। বালাই সমস্যা কোন ফসলে বেশী দেখা যায়? (জুম/একক ফসল/, শাক-সবজি/ ফল বাগান)
ক) আগাছা .... খ) পোকামাকড় .... গ) রোগবালাই ....

২১। বালাই সমস্যা কোন মৌসুমে/মাসে বেশী দেখা যায়? (জুম/একক ফসল/, শাক-সবজি/ ফল বাগান)
ক) আগাছা .... খ) পোকামাকড় .... গ) রোগবালাই ....

২২। বালাই সমস্যা আগের থেকে (৫-১০ বছর) বেড়েছে কি না? (বেড়েছে/কমেছে/পূর্বের মত আছে)
ক) আগাছা .... খ) পোকামাকড় .... গ) রোগবালাই ....

২৩। কত বছর যাবৎ বালাই নাশক ব্যবহার করেন?
ক) আগাছা .... খ) পোকামাকড় .... গ) রোগবালাই ....

২৪। বালাইনাশকের বর্তমান মাত্রা ৫/১০ বছর আগের চেয়ে বেড়েছে কি না ? (বেড়েছে/কমেছে/পূর্বের মত আছে)
ক) আগাছা .... খ) পোকামাকড় .... গ) রোগবালাই ....

২৫। বালাইনাশক ব্যবহার সম্পর্কিত তথ্যের উৎসঃ ....

২৬। উন্নত পদ্ধতিতে চাষাবাদ সম্পর্কিত প্রশিক্ষণ আছে কিনা? (√) দিন হাঁ/না
হাঁ হলে কারা প্রশিক্ষণ দিয়েছেন? ....

২৭। বালাইনাশকের নিরাপদ ব্যবহার সম্পর্কিত প্রশিক্ষণ আছে কিনা (√) দিন হাঁ/না
হাঁ হলে কারা প্রশিক্ষণ দিয়েছেন? ....

২৮। সমন্বিত বালাই ব্যবস্থাপনা সম্পর্কিত প্রশিক্ষণ আছে কিনা (√) দিন হাঁ/না
হাঁ হলে কারা প্রশিক্ষণ দিয়েছেন? ....

২৯। বালাইনাশক ব্যবহারে (মানব স্বাস্থ্যের /গবাদীপশুর/মৎস সম্পদেও/অন্যান্য পরিবেশগত) হাঁ/না
হাঁ হলে কোন ধরনের সমস্যা? ....