INSECT PESTS AND THEIR DAMAGE PATTERNS IN PADDY (*Oryza sativa* L.) IN SAPTARI DISTRICT, NEPAL

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Submitted to:

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April 2022

DECLARATION

I hereby declare that the work presented in this thesis has been done by myself, and has not been submitted elsewhere for the award of any degree. All sources of information have been specifically acknowledged by reference to the author(s) or institution(s).

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RECOMMENDATIONS

This is to recommend that the thesis entitled **"INSECT PESTS AND THEIR DAMAGE PATTERNS IN PADDY (*Oryza sativa* L.) IN SAPTARI DISTRICT, NEPAL"** has been carried out by Aanand Kumar Mali for the partial fulfillment of Master's Degree of Science in Zoology with special paper Entomology. This is his original work and has been carried out under my supervision. To the best of my knowledge, this thesis work has not been submitted for any other degree in any institutions.

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Abbreviations

Abbreviated form	Detail of abbreviations
GPS	Global Postioning System
JM	Jhapali Mansuli
SM	Sona Mansuli

ABSTRACT

This study focused on to identify insect pests and their damage patterns studies were conducted in two varieties of paddy plots in Gadhiya Village of Rajbiraj Municipality during rice growing season of 2019. Sampling field visits consist of three stages, starting from the vegetative growth stage, flowering stage and maturity (ripening) stages of the paddy growth stage during different time periods of a day. Two sampling methods were used, i.e. swinging a sweep net and ocular observation for insect pests collecting purposes. The sampling was done three periods of a day i.e. morning, afternoon and evening. This study composition recorded 14 insect pest species were founded that belongs to 12 families of eight orders found in paddy field. *Hieroglyphus banian* was the dominant species among all stages, followed by *Nilaparvata lugens, Leptocorisa acuta, Dicladispa armigera, Cnaphalocrosis medinalis, Stenchaetothrips bioformis, Spodoptera mauritia* pests were found in both varieties of paddy plant. Rice pest abundance shown in the field, a high relative abundance of Orthoptera (32.8%) pests was found, followed by Homoptera (19.1%), Hemiptera (15%), Heteroptera (12.9%), Lepidoptera (10.1%), Coleoptera (7.1%), Thysanoptera (1.9%) and Diptera (1.1%). For the total sampling period, the biological indices calculated consist of the Shannon-Wiener diversity index (H') is 2.43, Pileou's evenness index (J') is 0.92 in a SM variety whereas the value of H'=1.29 and J'=0.72 in JM variety. The study identified six damage patterns on the crop (leaf cutter or miner, stem borer, immature grains milk sucker, leaf roller, sapsucker, panicle cutter). Most of them (11) species were responsible for leaf-cutting or mining of the leaf blade and less (two) species were leaf rollers. Results indicated that diversity of insect pests was found more in paddy field cultivated ensured a good balance between the populations of pests and damage patterns for better paddy development. However, the periodic abundance was seen more in the afternoon than evening and morning. Diversified of insects can be potentially effective to conserve, use and promote biodiversity which helps for sustainable food security by yielding more productivity from the agricultural ecosystem in Saptari.

1. INTRODUCTION

1.1 Background

Rice (*Oryza sativa* L.) is cultivated most of the part of the world and is one of the staple foods for one-third of the world population. It is mostly grown in tropical and subtropical regions. Nepal comprises more than 1, 700 rice landraces within 60 to 3050 m height above sea level (Adhikari et al. 2018). The insect pest infestation is one of the major limiting factors on rice production. All of the stages of rice growth their plant parts are susceptible to insect feeding on time of sowing till harvest. The rice plant is subject to attack by more than 100 species of insects among them, 20 can cause economic damage (Pathak and Khan 1994). Warm and humid environments make a hospitable condition for the proliferation of different species of insect pests in the rice fields (Edirisinghe and Bambaradeniya 2006, Pathak and Khan 1994). Additionally, heavily fertilized, high tillering, variety of growth stages in a short time period favors the build-up of pest population, which result the average rice yield loss due to various insect pests was estimated to be 31.5% in Asia and 21 % in North and Central America (Pathak and Khan 1994).

Farmers in Lamjung, Nepal also reported as insect pests are a serious limitation in rice production with rice Gundhi bug followed by yellow stem borer as the major devastating insects in standing crop (Adhikari et al. 2018). Insect pests constitute one of the major yield reducing factors in rice production. Further, there has been enormous storage loss due to the ineffective store house and severe storage pest attack. Annual crop loss due to insect and vertebrate pests is estimated at about 25% to 38% (Lamsal 2016). Insect pests not only reduce the yield but also increase the production and storage cost causing both quantitative and qualitative losses. There are more than 100 insect pests that cause damage to rice-crop. Among them, stem borers, gall midge, plant hoppers, leaf fodders, rice hispa, gundhi bug, case worm are the most important ones. The biology and ecology of these insect pests of the paddy crop have been dealt in detail by Pathak and Khan (1994), Dale (1994), Chaudhary et al. (2002), Islam et al. (2004), Wopereis et al. (2009) and others. However, unsprayed, irrigated rice fields have relatively few insect pest problems. This is largely attributed to natural biological control, which keep plant hoppers, most notably BPH, and other potential pests in check (Kenmore et al. 1984, Way and Heong 1994).

Among various constraints of good rice production, infestation of different insect species is very important. The rice stem borers are the principal devastators and responsible for economic crop losses under field condition (Mahar and Hakro1979). They are common and serious pests in Asian countries responsible for annual damages of 5-10% of rice crops (Pathak and Khan 1994). Heavily infestation may cause yield loss up to 80% (Rubia-Sanchez et al. 1997). Five species of rice stem borers have been

identified available in South East-Asia namely; Dark headed stem borer (DHSB), *Chilo polychrysus* (Meyrick); Yellow stem borer (YSB), *Scirpophaga incertulas* (Walker); Pink stem borer (PSB), *Sesamia inferens* (Walker); Stripped stem borer (SSB), *Chilo supressalis* (Meyrick) and White borer (WB), *Scirpophaga innotata* (Walker) (DRR 2006). YSB is the most destructive insect pests of rice crop (Mahar et al., 1985) and responsible for an annual yield loss of 10-15% with local disastrous outbreaks causing up to 60% damage (Catling and Islam 1981; Daryaei 2005). It is the most important insect pest of rice in Bangladesh (Islam and Hassan, 1999) and also considered a major pest in Asia (Torri 1971). *Scirpophaga incertulas* (Walker) is a mono esophagus pest of paddy that belongs to order Lepidoptera and family Pyralidae. This pest is the most destructive pest and found almost all regions of the world. Symptomatic of this pest is characterized by "dead heart" in the hill at vegetative stage and "white ear" in panicle at reproductive stage. The last instars of larvae created an instance outlet hole and pupate in silken cocoons inside the larval tunnel in the base of the plant (Sarwar 2012a, 2012b). When infestation occurs at flowering stage, the ear head become chaffy (Jadho and Khurad 2012). The population of *N. virescens* dominant in the tropical area including Srilanka (Fernado1967), Philippines (Nasu 1967) and India, Burma, China, Taiwan, Malaysia (Ghauri 1971). *Nephotettix virescens* and *Nilaparvata lugens* are sucking pest of rice that belong to order Hemiptera and family Ciccadellidae and Delphacidae respectively, damage symptoms of *Nephotettix virescens* characterized by "Yellow/brown leaves" while *Nilaparvata lugens* characterized by "Hopper burn". The higher population of leaf folder (*Cnaphalocrocis medinalis*) was found higher in kharif season during 1995-1997 by Prasad Kumar (2003). The young larvae of leaf folder feeds on tender the leaves without folding them while older larvae feed inside older folded leaves. Leaf folder belongs to order Lepidoptera and family Pyralidae. Gall midge (*Orseolia oryzae*) belongs to the order Diptera and family Ceccidomyiidae, damage symptom of this pest is characterized by "onion leaf" and "silver shoot". The stem borer, brown plant hopper, gall midge and leaf hopper are among important pests in Southeast Asia and China while gall midge, brown plant hopper and yellow stem borer report for major rice yield losses in South Asia (Sardesai et al. 2001). Insect pests damage plant parts by chewing plant tissues, boring into stems or sucking fluid saps from stem and grains. Damages caused by insect pests bother physiology of plants and result in to lower crop yield (Nasiruddin and Roy 2012).

The present study was conducted to gather information about type of insect pests found during different stages of the paddy plant in order to develop elements of an integrated control program against rice pest by the farmers in the local cropping system. Population density of the pest complex in different growth stages of the rice plant would be useful to decide the appropriate time of insecticide application. The specific objective of this study was to assess the abundance, damage patterns and diversity of insect pests in rice of two varieties.

1.2. Objectives

1.2.1. General objective

- To identify the insect pests in two varieties of paddy

1.2.2. Specific objectives

- To study damage patterns in paddy
- To investigate the periodic abundance and diversity of the insect pests

1.3. Rationale of the study

1.3.1. Justification of the study

This research signifies the documentation of pest identification from the proposed study area. So, this study helps to find the current status of paddy pests for their better management.

1.3.2. Significance of the study

This study has focused on collection of information related to insect pests used to occur at various stages of crop that make easy to implement suitable tactics for their control and yield more crop grains in Saptari District. In addition, this study aims to provide periodic abundance of the specific species in different growth stages of the crops, so that control strategy of insect pests would be applied with such reference.

1.3.3. Limitation of the study

- It was difficult to identify some species of pest through ocular observation.

2. LITERATURE REVIEW

Catling (1992) have studied that the highly insect host plant relationship and the adaptive characteristics to an aquatic environment strongly and suggested that yellow stem borer originated in the deep-water Rice environment.

Siddique (1992) estimated annual loss of rice in Bangladesh due to insect pests and diseases amount 1.5 to 2.0 million tons.

Ranasinghe (1992) said that *Scirpophaga incertulas* could attack most of the growing stages of rice plant, beginning with seedling through tillering and up to ear setting.

Pathak and khan (1994) reported that rice stem borers were evident regularly throughout the rice growing seasons and attacked plants from seedling to maturity stages. They also reported that the maximum population of adults and grubs of rice hispa were found at mid-tillering stage.

An estimate made at National Rice Research Institute, Cuttack suggests that every 1% increase in stem borer damage registered a loss of 0.28% at vegetative stage and 0.62% at headings stage.

Tripathy and Senapati (1995) estimated in Odisha, that about 27% grain yield loss has been found in semi-deep water rice due to stem borer infestation in heading stage and every 1% increase the grain yield loss was 29-49 kg/ha in different varieties.

Sontakke and Rath (1998) found leaf damage of 15.9% in a local variety and 32.4% in a hybrid.

The leaf folder infestation at grain filling stage was more detrimental which was in accordance with the finding made by Saika and Parameswaran (1999).

Tripathy et al. (1999) founded two peaks of yellow stem borer (*S. incertulas*), of which first was during the last week of September and another during second week of November which coincided with the dough stage of rice.

Haque et al. (2000) indicated that under high densities of rice hispa, the leaf growth of younger plants (with greater than 20% leaf damage) is severely retarded.

Banwo (2002) found five Orders of insect pests (Coleoptera, Diptera, Hemiptera, Lepidoptera and Orthroptera) in rice crop field and also discussed as stem borer, Stem and root feeders, leaf and panicle feeders.

Islam et al. (2003) have been recorded 266 species of rice pests of these 42 species are economically important in Bangladesh.

Regarding natural enemy population occurrence, similar type findings were reported by (Khan and Mishra 2003) and (Vijay and Patil 2004), wherein they found that the spider population was directly related to growth stages of the rice plants.

Ragini et al. (2005) conducted a survey to evaluate the seasonal occurrence and relative abundance of three rice stem borer species i.e. Yellow stem borers; Pink stem borer and dark headed borer. She founded that YSB was most predominant species in June- Sept (60%) and Oct-Jan (48.43%), PSB was as abundant as YSB in Oct-Jan (48.43%). YSB infestation was predominant from early tillering to maximum tillering stage and decreased gradually with increasing PSB infestation from the flowering stage.

Puspakumari and Tiwari (2005) noted the population of ear-head bug (*L. acuta*) just before flowering of the crop and highest number was recorded at the milky stage of the crop.

Prakash et al. (2005) concluded that among major insect pest of rice stem borer has shown geographical variation in its species composition like Yellow stem borer, white stem borer, dark headed borer and pink borer across the country.

Haq et al.(2006) found that Rice caseworm *(Nymphula sp.)* mostly damage the rice plants 2 to 4 weeks after transplantation while incidence occurred at 15th August and subsequent transplanting dates during T. Aman (July-December) and highest leaf damage was observed in case of mid-October Planting.

Ananthakrishna (2007) sorted climate change will affect the pest incidences and their severity as limiting factors as well as favorableness of growing conditions.

Khan and Alam (2007) reported that diversity indices, species richness and equitability of insect pests and natural enemies were affected by the combined effect of management practices and rice growth stages.

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Rani et al. (2007) conducted a field experiment to investigate the diversity of rice leaf folders and their natural enemies. They observed three species of rice leaf folders viz., *Cnaphallocrocis medinalis* (Guenee), *Marasmia pantalis* (Bradley) and *Marasmia ruralis* (Walker) among which former was dominant and found throughout the year.

Alam (2008) carried out a survey of rice insect pests conducted during 1983–87 in Nigeria revealed 70 species of pests, 14 parasitoids and two predators. Both incidence and severity of

pests varied considerably across different climatic zones and rice agro-ecosystems. Thirteen insects were classified as major pests. The brown plant hopper, *Nilaparvata maeander* Fennah, and whitefly, *Aleurocybotus indicus D&S* are potentially serious pests. The insect pest situation will probably change in Nigeria as the use of modern inputs increases, based on experience in Asia.

Desai (2008) showed that the severity of the pest was seen at the reproductive stage of crop.
Thapa and Tiwari (2010) reported that brown plant hoppers, leaf folders, yellow stem borer are the major pests.

Chandramani et al. (2010) said that Among the key pests of rice in India, Yellow stem borer, brown plant hopper, white backed plant hopper, gall midge, leaf folder, case worm and gundhi bug were found to cause substantial damage to crop. Moreover, loss incurred reason behind it was different insect pests of rice are reported to the tune of 15,120 million rupees which works out to be 18.6% total losses.

Hugar et al. (2010) reported that the biology of yellow stem borer showed that eggs were oval, flattened and creamy white in both aerobic and transplanted rice.
Tiwari et al. (2010) recorded white stem borer and pink stem borer both were to occur along with yellow stem borer.

Sankpal (2011) observed peak level of *S. incertulas* at vegetative and reproductive stage, while Gole (2012) stated the incidence of *S. incertulas* from early stage to the harvest of the crop.

Nasiruddin and Roy (2012a,2012b) reported that 35 species insect pests belonging to 30 genera under 13 families with nine species, Order Lepidoptera three families with 11 species and Order Coleoptera one family with one species. Hemiptera are seen the most abundance order followed by Orthoptera, Lepidoptera and Coleoptera in rice plant. Though Yellow stem borer is the dominant species, White stem borer and pink stem borer species were found in hill region parts of Punjab and Haryana in north India and Kerela in south India.

Nasiruddin and Roy (2012c) observed that most of rice plant parts are exposed to pest attack from period of showing to harvest. Insect damage plant parts by chewing plant tissues, boring into stem and grains. Damages caused by insects disturb physiology of plants and result in lower crop yield.

Alam (2013) conducted the survey and assessment at different districts of Bangladesh on insect management technologies and environmental impact in rice ecosystem in 2011. Farmers usually practiced perching and insecticides application for management of brown plant hopper (*Nilaparvata lugens*) and stem borer (*Scirpophaga incertulas*) insects in rice ecosystem. Light trap, perching and insecticides were covered 33, 40 and 66% of total surveyed area for management of brown plant hopper (BPH), respectively. On the other hand, 26, 66 and 80% of total surveyed areas were followed of light trap, perching and insecticides for controlling of stem borer insect, respectively.

Rehaman et al. (2014) tested the relative abundance of yellow stem borer, pink stem borer, dark headed stem borer, white stem borer, stripped stem borer and nine different natural enemies and stem borers were highest in tillering stage and lowest in seedling stage.

Ane and Hussain (2015) conducted study in June to September and resulted out Plant hoppers (Brown Plant Hopper and White-back Plant Hopper) and Leaf hoppers (Green Leaf Hopper and Zigzag Leaf Hopper) were widely distributed in paddy field.

Gangwar (2015) conducted the trail on lifecycle and abundance of rice leaf folder, Before existence of high yielding and Basmati rice varieties leaf folder has been considered a minor pest of rice growing areas but present time it occur in major pest of rice and cause severe yield loss.

Ahmad et al. (2016) conducted six years entomological survey to evaluate the percentage level of pest infestation on fine, coarse and hybrid varieties of rice nursery and crop during Kharif 2010-2015 in agro-ecological zone of District Sialkot Punjab-Pakistan. During entomological survey they recorded that rice nursery mostly affected by Toka (Grasshopper); Yellow Stem Borer (YSB); White Stem Borer (WSB). Maximum infestation was recorded by Toka (17.67%); Leaf Folder (0%); Borer (4.15%) with temperature ranges 22.97-35.80oC, Relative Humidity (RH) (49.70%) and rainfall 333.80mm. However, 0% infestation was recorded by hopper and hispa during 2011. However, 15.99% attack was recorded by toka and borer (4.21%) with temperature ranges 22.50- 36.12oC; RH (59.50%) and rain fall (118.30mm). After that 0% pest attack was recorded by leaf folder; hopper and hispa during 2013. During 2015, 14.32% pest infestation was recorded by grasshopper and borer (3.02%) with temperature ranges 23.91- 35.27oC with RH (60.27%) and 163.20mm rain fall.

Baskaran et al. (2017) determined seasonal incidences of stem borer and leaf folder in wetland rice ecosystem. Three species of stem borer including yellow stem borer, white stem borer and stripped stem borer were found highest attacking in rice crop as compared them,

S.incertulas dominated.

Chhavi (2017) Leaf folder show highest infestation at reproductive stage and reduce yield up to 6.2 respectively.

Mondal et al. (2017) found out three main factors which cause maximum yield loss weed 37.02% followed by insect pest 27.9% and disease15.6%. Out of 27.9% damage caused by different insect stem borer alone causes 8.7% and it was positive correlated with 'dead heart' or 'white head' infestations of vegetative, reproductive and mature phases of crop.

Singh and Singh (2017) conducted survey on Yellow Stem Borer, Green Leaf Hopper, Brown Plant Hopper, Leaf folder and gall midge on BPT-5204 variety of paddy found that yellow stem borer and green leaf hopper were considerably high during vegetative and reproductive stage.

Siregar et al. (2017) studied insect diversity in paddy plots in Lae Parira Village, Dairi. Eight sampling visits consists of 4 phases, starting from the seedlings phase, flowering phase, milky phase and ripening of the grains phase. There are four sampling methods were used, i.e. sweeping net, sticky yellow trap, and core sampler. The total of 1365 individuals of insect, representing (37) species in (24) families and (8) orders. The most abundant insects were *C.medinalis* (178), *M.vittaticcollis* (83), *N.viridula* (81), *N.lugen* (78), *L.oratorius* (73) and *S.coarctata* (71). Family of Crambidae (Lepidoptera), Gryllidae (Orthoptera) and Pentatomidae from order Hemiptera and recorded the highest number of individuals for the whole study period, respectively. The comparison insects used three tools such as sweeping net (482 individuals), sticky yellow trap (730), core sampler (89) and pit fall trap (64).

Adhikari et al. (2018) said that farmers in Lamjung, Nepal reported as the insect pest are the serious constraint in rice production with rice gundhi bug followed by stem borer as the major devastating insects in standing crop. The number of insect species was highest at the booting and heading stages of rice in Chitwan, (9), and in the tillering stage in Lamjung (2). In these two areas, the highest number of *Nymphula depunctalis* Guenée occurred at the tillering stage.

Reuolin et al. (2018) conducted a study to assess the influence of YSB on different stages of rice crop. They recorded different parameter of climatic conditions which effect the population rate and observed maximum dead heart damage (10.47%) at 60 DAP and minimum (3.98%) at 45 DAP by YSB.

Deshwal et al. (2019) found 12 insect pests' species which belongs to six orders (i.e. Lepidoptera, Homoptera, Heteroptera, Coleoptera, Isoptera and Orthoptera) in Basmati rice of western zone of Utter Pradesh during Manson season.

Gyawali et al. (2019) studied on diversity and abundance of insects in rice field was conducted at farmer field of Lamahi, Dang during July to October in 2019. Insects were collected using sweep net and light trap. Overall, 414 insect specimens representing 11 families and 8 orders were collected during the period. Grasshopper (23.98%) with including all species was the most abundance insect found in rice field as it followed by brown plant hopper (16.62%). Among the eight insect orders captured Orthoptera (29.16%) was the most abundance insect order followed by Homoptera (16.62%). As the diversity of insect pest in this area may responsible economic losses was found which will be useful to adapt appropriate management practices to keep them at normal area. The presence of natural enemies should conserve to enhance the natural biological control of insect pests.

Patil et al. (2020) concluded that seasonal incidence revealed to the population of Brown plant hopper was appeared in rice crop during first week of August i.e. after getting medium shower of rain and the population increase with increase in rainfall.

Singh and Kumari (2020) studied that green leaf hopper play major important role in infestation of rice crop followed by YSB, Brown Plant Hopper, Gallmidge and Leaf folder.

Ali et al. (2021) concluded that rice fields need to be monitored at 7-10 days intervals for checking levels of pest infestation as 23 insect pest species are economically important for rice crop.

Mitku et al. (2021) conducted field surveys in 2018 and 2020 rainy season to generate baseline information on the type of pests prevailing in rice crop. The survey was conducted in South Gondar, three districts. Insect pests were determined by visual search for damages done by insects throughout the field. The current survey found that more than 13 insect pest of namely, stalk eyed fly, stem borer, leaf hopper as leaf/stem feeding and rice bug and sting bugs are among grain sucking insect pest, and whorl maggot, cricket, grass hopper and termite also found in the study area. Furthermore, our study found that a new insect in the study area named as creatonatus sp. which feed on rice leaf. Additionally, the study found that more than 6 natural enemies of rice insect pests. Some of the natural enemies are damselfly, dragonfly and spider, beetle, lacewing and wasps found dominantly in the study area.

3. MATERIALS AND METHODS

3.1. Study Area

The study was conducted in the Gadhiya village (Lat: 26°56'N and Long: 86°74'E), Rajbiraj Municipality, Saptari district, Madhesh Province, lowland Nepal. The study site was about 80 meters above sea level and lies in the North-East of Rajbiraj city. The site has been considered as the hub of paddy cultivation. Most of the farmers have been depended in paddy cultivation as the paddy is their major food sources.

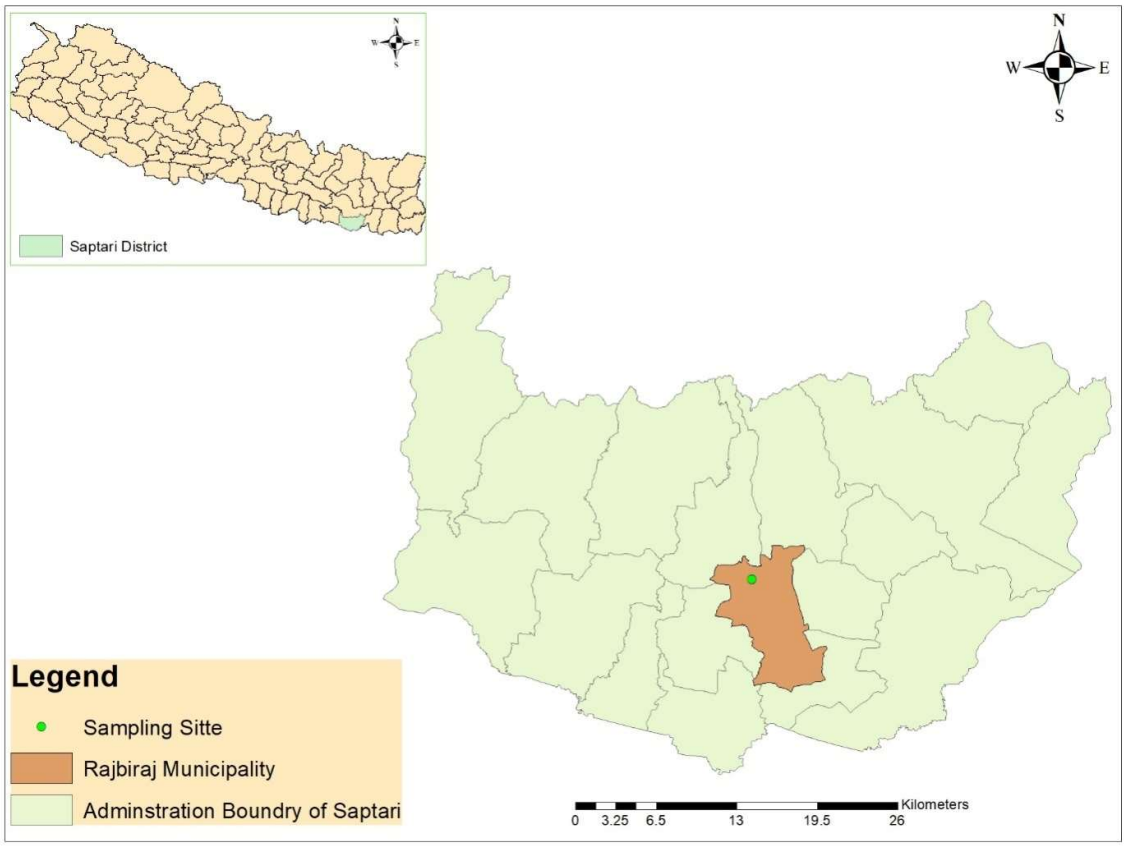

Figure 1: Study map showing sampling site

The climatic condition of the study site is humid as it lies in the sub-tropical region of Nepal. The average rainfall in the rice cultivation periods (June and July) of this area ranges from 200-250 mm (Nepal parichay 8thed.). The people of the areas mostly engaged in rice cultivation, basically, the Monsoon season rice is grown. The near study area surrounds about 500 hectares of farmland where mostly paddy crops are grown during Monsoon periods (June to November). The study area is covered with fertile land having good productivity of crops.

3.2. Study Rice Varieties

For the valuation of pests, two varieties of rice; SM and JM were selected as the purposive survey of insect pests.

Morphological characteristics of studied rice varieties

I) Sona Mansuli (SM) variety (Khanal and Badal 2015)

Color of plant: Dark Green

Size of plant: 2.5 Feet

Panicle length: 21 cm

Straw: Less in comparison of JM

Shape of leaf blade: Thin and narrow portion of the leaf

Color of grain: Brown

Size of grain: 6 mm

Shape of grain: Longer and flat type

Maturity: 160 days

II) Jhapali Mansuli (JM) / Kanchi Mansuli variety (Khanal and Badal 2015)

Color of plant: Light Green

Size of plant: 3.25 feet

Panicle length: 23 cm

Straw: More in comparison of SM

Shape of leaf blade: Thin, elongated and flat portion of the leaf

Color of grain: Light yellow

Size of grain: 5 mm

Shape of grain: Shorter and cylindrical type

Maturity: 145 days

3.3. Sampling Procedures

3.3.1. Sampling design

The study sites were designed with dividing with four sampling plots (each plot size 20*20 m). The inter distance of 100 m of each plot has been prepared.

Sampling materials used during Field visits were:

- Sweeping net
- Gloves
- Hand lenses

- Ethanol (70%)
- Formalin
- Small jars
- Card board paper
- Pins
- Notebook
- GPS device

3.3.2. Sampling periods

A sampling of insect pests was done in three different growth stages {Tillering (vegetative) (July)}, {milking (September)} and {mature (November)} of both the variety of rice during rice growing season of 2019. Field visits were conducted three periods of the day; morning (08:00 to 10:00 AM), afternoon time (12:00 to 02:00 PM) to evening time (04:00 to 06:00 PM).

3.3.3. Sampling techniques

Insect pests were collected using a sweep net and ocular observation in the field within the prepared plots. Before collection, close observation of their pattern of damages was observed. During field collection, the collected specimens were stored in ethanol (70%) for identification after killing them in the killing jar that consists of formalin. Individual pest species were counted from field plots and noted down in a field notebook. The geographical coordinates of the study area were recorded with the help of a GPS device.

3.4. Insect pests' identification

Collected and visualized insect pests were identified with help of using taxonomic literature and studied morphological characters (Borror and Delong 2005).Unidentified pest species were identified by tallying with the specimen that was previously identified from Natural History Museum, Swayambhu (NHM), and National Agricultural Research Council, Lalitpur (NARC).

3.5. Data processing and statistical analysis

Three parameters to access the insect pest diversity of the recorded species were calculated on Excel sheet. The Shannon index, Evenness formula, and Relative abundance were used for the assessment of insect species diversity as follows (Stiling 1999)

Shannon-Weiner Diversity Index (H') = $\mathbf{-\Sigma pi \times ln(pi)}$

Where,

H =Shannon Diversity Index

Ln = Log Normal

Pi = Proportion of individuals of species I = ni/N

Diversity index values (H') < 1.0 then the diversity is considered as low, if the value of diversity index (H') > 1.0 - 3.0 then the diversity is considered as medium, whereas the value of diversity index (H') > 3.0 then its diversity is considered as high.

The evenness of insect pests at site was calculated using Pielou's Evenness index (J').

$J = H'/ H_{max}$

Where,

J = Pielou's Evenness index

H' = Shannon Diversity index

H_{max}= Natural logarithm of species richness {ln(S)}

The range of Evenness index (J) is 0 to 1.The pielou's Evenness is less even when have value nearer to 0 and more even when nearer to 1.

$$\textbf{Relative abundance} = \frac{\textit{Total no. of particular species}}{\textit{Total no. of all the species found}} \times 100$$

The range of index value for the Abundance categories were determined as: (Oo et al. 2020)

Rare Species = (0.1 - 2.0) Common = (6.1 - 8.0) Uncommon = (2.1 -4.0)

Frequent = (4.1 - 6.0) Abundant = (8.1 - above)

4. RESULTS

4.1. **Insect Pests Diversity, Relative abundance, and their Damage patterns**

A total of fourteen and six species of insect pests were found in SM and JM varieties rice respectively at different growth stages (Table 1). *Hieroglyphus banian* was the only pest found in all three growth stages of both varieties of rice. Similarly, the insect pests namely; *Leptocorisa acuta, Dicladispa armigera, Cnaphalocrocis medinalis, Stenchaetothrips bioformis* and *Spodoptera mauritia* were found manifesting two different growth stages of the rice (Table 1). In SM, *Nilaparvata lugens* and *Brevennia rehi* were found in all three growth stages whereas, the insect pests; *Hysteroneura setariae*, *Orseoliaoryzae*, *Scotinophara coarctata*, *Nymphula depunctalis*, *Scirphophaga incertulas*, and *Nephotettix virescens* were registered manifesting two growth stages (vegetative and flowering) of SM rice (Table 1). However, in terms of JM, the insect pest singly manifesting the single growth stage was not found throughout the study periods. A detailed account of insect pests recorded in three different growth stages of two varieties of paddy was given in Table 1.

During the flowering or milking stages of paddy, the relative abundance of pests was seen more compared to the vegetative and mature stages of the crop. As rice pest abundance in the field, a high relative abundance of Orthoptera (32.8%) pests was found, followed by Homoptera (19.1%), Hemiptera (15%), Heteroptera (12.9%), Lepidoptera (10.1%), Coleoptera (7.1%), Thysanoptera (1.9%) and Diptera (1.1%) (Table2). The Shannon-Weiner Diversity Index shows significantly more in the SM (H'= 2.43) than the JM (H'=1.24) whereas the Pileou's Evenness is also seen in a more evenly distributed pests' species in SM (J=0.92) than in JM (J=0.69) (Table 3).

A diversified insect pest ecosystem results in significant economic loss to crop productivity by causing several patterns of damage at different growth stages of the crop. This study identified six damage patterns on the crop (leaf cutter or miner, stem borer, immature grains milk sucker, leaf roller, sapsucker, panicle cutter). During the study periods, 11 species were responsible for leaf-cutting or mining, leaf blade, five species were stem borers, two species were leaf rollers, three species were immature grain milk suckers, nine species were sapsuckers and five species of them are Panicle cutters (Table 4). *Hieroglyphus banian* was the pest that was found actively participated in two damage patterns (i.e. leaf cutter and panicle cutter) in both verities of paddy crop of all three growth stages and *Nilaparvata*

lugens was the insect pest found only SM at all growth stages participated in two damage patterns (i.e. leaf miner and sapsucker). The detailed damage patterns of the insect pests in the two paddy crops varieties are shown in Table 4.

Table 1:Insect pests of paddy crops of three growth stages. (SM=a and JM=b)

S.N.	Scientific name	Order: Family	Growth Stages		
			Vegetative	Flowering	Maturity
1.	*Hieroglyphus banian*	Orthoptera: Acrididae	a and b	a and b	a and b
2.	*Hysteroneura setariae*	Homoptera: Aphididae	a	a	-
3.	*Orseolia oryzae*	Diptera: Cecidomyiidae	a	a	-
4.	*Leptocorisa acuta*	Heteroptera: Coreidae	-	a and b	a and b
5.	*Dicladispa armigera*	Coleoptera:Hispidae	a	a and b	a and b
6.	*Stenchaetothrips bioformis*	Thysanoptera: Thripidae	a and b	a	-
7.	*Scotinophara coarctata*	Hemiptera: Pentatomidae	a	a	-
8.	*Nilaparvata lugens*	Homoptera: Delphacidae	a	a	a
9.	*Nymphula depunctalis*	Lepidoptera: Pyralidae	a	a	-
10.	*Scirphophaga incertulas*	Lepidoptera:Noctuidae	a	a	-
11.	*Brevennia rehi*	Hemiptera: Pseudoccidae	a	a	a
12.	*Cnaphalocrosis medinalis*	Lepidoptera: Pyralidae	a and b	a and b	-
13.	*Spodoptera mauritia*	Lepidoptera:Noctuidae	-	a and b	a and b
14.	*Nephotettix virescens*	Homoptera: Cicadellidae	a	a	-

Table 2: Relative abundance of insect pests during different growth stages of the crop in order based.

Orders	Vegetative	Flowering	Maturity	Total	R.A. (%)
Orthoptera	12.3	31.6	12.5	56.4	32.8
Homoptera	9.4	19.8	3.6	32.8	19.1
Hemiptera	6.7	15.2	3.9	25.8	15
Heteroptera	0	14.1	8	22.1	12.9
Lepidoptera	4.1	11.5	1.8	17.4	10.1
Coleoptera	3	8	1.1	12.1	7.1
Thysanoptera	1.1	2.1	0	3.2	1.9
Diptera	0.7	1.2	0	1.9	1.1
Total	37.3	103.5	30.9	171.7	100

Table 3: Shannon-Weiner Diversity Index (H') and Pielou's Evenness Index (J') of both paddy crops

Paddy Crops	H'	J'
SM	2.43	0.92
JM	1.24	0.69

Table 4: Damage patterns: (Vegetative=*, Flowering=** and Maturity=***) (1= role; 0=non-role)

Insect Pests	Orders: Families	Stages	Damage patterns					
			Leaf cutter or Miner (Defoliated)	Stem borer	Leaf roller	Immature grain milk sucker	Sap Sucker	Panicle cutter
Hieroglyphus banian	Orthoptera: Acrididae	*,**and ***	1	0	0	0	0	1
Hysteroneura setariae	Homoptera: Aphididae	* and**	0	0	0	0	1	0
Orseolia oryzae	Diptera: Cecidomyiidae	* and**	0	1	0	0	1	0

Leptocorisa acuta	Heteroptera: Coreidae	** and***	0	0	0	1	0	0
Dicladispa armigera	Coleoptera:Hispidae	** and ***	1	0	0	0	0	1
Stenchaetothrips bioformis	Thysanoptera: Thripidae	* and **	1	0	0	0	1	0
Scotinophara coarctata	Hemiptera: Pentatomidae	* and **	1	1	0	0	0	1
Nilaparvata lugens	Homoptera: Delphacidae	*,** and ***	1	0	0	0	1	0
Nymphula depunctalis	Lepidoptera: Pyralidae	* and **	1	0	0	0	1	0
Scirphophaga incertulas	Lepidoptera: Noctuidae	* and **	1	1	1	1	1	1
Brevennia rehi	Hemiptera: Pseudoccidae	*and**	1	0	0	0	1	0
Cnaphalocrosis medinalis	Lepidoptera: Pyralidae	* and **	1	1	1	0	0	1
Spodoptera mauritia	Lepidoptera: Noctuidae	** and ***	1	1	0	1	1	0
Nephotettix virescens	Homoptera: Cicadellidae	* and**	1	0	0	0	1	0

4.2. Periodic abundance of insect pests

The surveys have been conducted three periods on every sampling day. During the study periods, all the insect pests (14) have been recorded during the afternoon and evening periods (Fig 2). However, the pests were significantly more abundant during afternoon than evening periods (Appendix 1). During the morning period, a total of 12 insect pest species were recorded contributing less abundance. The Shannon-Weiner Diversity Index shows less value of (H'=2.28) whereas Pielou's Evenness was also less (J'=0.91) in the morning. Five insect pests viz. *Dicladispa armigera, Nephotettix virescens, Leptocorisa acuta*, *Hierogluphus banian* and *Brevennia rehi* were the most abundant whereas three pest viz. *Cnaphalocrosis medinalis*, *Scotinophara coarctata*, *Orseolia oryzae* were less abundant insect pests recorded during the afternoon (Fig. 2). Likewise, among 14 insect pests in the afternoon, seven were

the most abundant viz. *Hieroglyphus banian, Leptocorisa acuta, Dicladispa armigera, Hysteroneura setariae, Nilaparvata lugens, Scirphophaga incertulas,* and *Nephotettix virescens* whereas four were less abundant viz. *Spodoptera mauritia, Cnaphalocrosis medinalis, Nymphula depunctalis* and *Scotinophara coarctata.* In the evening time, similar types of insect pests (14) were found but their abundance slightly declined in comparison to the afternoon. Six of them were most abundant at the evening which is quite a bit similar to the morning (having one species more abundant than morning) *viz*. *Hierogluphus banian, Leptocorisa acuta, Dicladispa armigera, Brevennia rehi, Nilaparvata lugens* and *Nephotettix virescens* whereas two insect pests were less abundantly found viz. *Spodoptera mauritia* and *Nymphula depunctalis.* The Shannon-Weiner Diversity Index Shown value of (H')=2.49 and (H')=2.38 whereas Pielou's Evenness (J')=0.94 and (J')=0.90 in the afternoon and evening respectively. The diversity of insect pests was more diverse and even during the afternoon period and slightly less in evening than afternoon whereas less diverse in the morning shown in Table.

Table 5: Shannon-Weiner Diversity Index (H') and Pielou's Evenness Index (J') during the study periods

Periodic Diversity	H'	J'
Morning	2.28	0.91
Afternoon	2.49	0.94
Evening	2.38	0.90

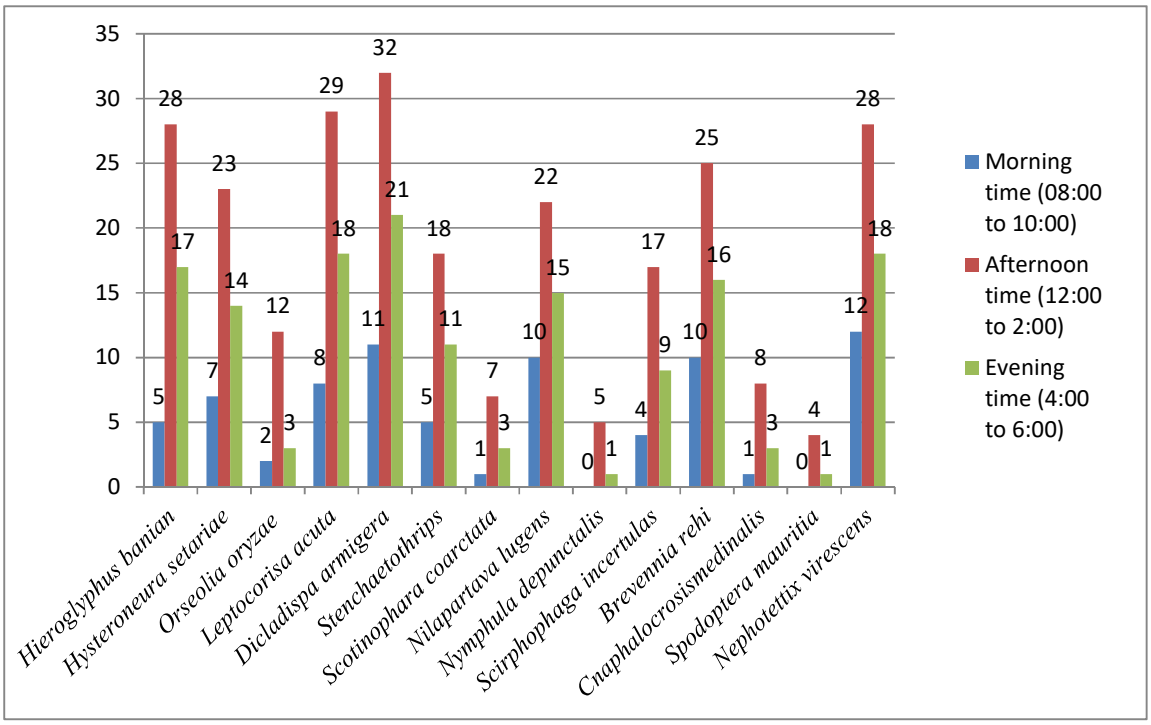

Figure 2: Bar diagram of activation period of insect pests

5. DISCUSSION

In this study, 14 pests found in the SM variety, and six pests were found in JM variety of rice. As there is no published survey information on major insect pests of rice in the Saptari District including Rajbiraj Municipality of Gadhiya village. As this finding shows the highest number of *Hieroglyphus banian* in the rice such related result carried out by (Gyawali et al. 2019). A survey was done in Lamjung District found quite similar results they got the highest number of Grasshoppers (40%) was tapped in the sweep net followed by Dragonflies (25%) and the least honeybee (2%) during the day. Insect captured in the light trap was the highest number of insects trapped was the Brown plant hopper (23%) followed by different species of moth (22%), grasshopper (17%) was found while surveying the rice field (Gyawali et al. 2019).

Nasiruddin and Roy (2012) found hemipterans were the most abundant order followed by Orthoptera, Lepidoptera, and Coleoptera whereas this present study results out that Orthopterans were the most abundance order. A study in China reported Orthoptera, Lepidoptera, Hemiptera, and Coleoptera insect order as the most abundance order according to (Chen et al. 2011) which is similar to the present findings. Deshwal et al. (2019) also found 12 insect pests' spp. that belong to six orders (i.e. Lepidoptera, Homoptera, Heteroptera, Coleoptera, Isoptera, and Orthoptera) in Basmati rice of the western zone of Utter Pradesh during Manson season which is quite related to this study as this survey found 14 insect pests species belongs to eight orders (i.e. Orthoptera, Homoptera, Hemiptera, Heteroptera, Lepidoptera, Coleoptera, Thysanoptera, and Diptera).

Six year entomological survey was conducted to evaluate the percentage level of pest infestation of paddy crop of different varieties in agro-ecological zone by (Ahmad et al.2016) recorded that maximum infestation were done by grasshopper (17.67%), Leaf folder (6.65%), Borer(2.53%), hopper(0.94%) and hispa (0.24%). Somehow even type survey done by Mitku et al. (2021) founded that more more than 13 pests namely, Stalk eyed fly, stem borer, leaf hopper as leaf/stem feeding and rice bug and sting bugs were among grain sucking insect pests, and whorl maggot, cricket, grasshopper and termite also recorded in the study area. As this study shows a similar type of study was also conducted by (Ane and Hussain 2015) from June to September and resulted in plant hoppers (Brown Plant Hopper and White-back Plant Hopper) and Leafhoppers (Green Leaf Hopper and Zigzag Leaf Hopper) being

widely distributed in paddy field and again in other study Grasshopper abundance likewise study done in Uttar Pradesh of India also reported grasshoppers as most abundance insect found in the rice field (Ane and Hussian 2016).Similar studies done for recording insect pests and damage patterns by Banwo (2002) found five Orders of insect pests (Coleoptera, Diptera, Hemiptera, Lepidoptera, and Orthroptera) in the rice crop fields and also discussed as stem borer, Stem and root feeders, leaf and panicle feeders.

Puspakumari and Tiwari (2005) have also noted the population of ear-head bug (*L. acuta*) just before flowering of the crop and highest number was recorded at the milky stage of the crop which is associated with this study as it also shows more abundance of insect pests during the flowering stage. As this study find out quite similar insect pests were studied by Singh and Kumari (2020) found that the green leafhopper plays a major important role in the infestation of rice crops followed by Yellow Stem Borer, Brown Plant Hopper, Gall midge, and Leaf folder.

A survey and surveillance of major insect pests of rice by Singh and Singh (2015) support the present finding. In their finding, *Nephotettix virescens* incidence induces yellow or brown color of leaves while *Nilaparvata lugens* incidence characterized by "Hopper burn" symptom of hills. *Nephotettix virescens* and *Nilaparvata lugens* both are much active at the vegetative and flowering stage of paddy growth but in this finding *Nilapravata lugens* found in the maturity stage too and its incidence was found in only the vegetative phase as both of them seen only in SM variety of rice crop. *Hieroglyphus banian* was found in both varieties of the rice role in all growth stages. *Leptocorisa acuta* was found during flowering and maturity stage whereas *Dicladispa armigera* found in all three stages of SM variety. This type of study was done previously by Singh and Singh (2014) for identify insect pests their finding shows incidence of 34 insect pests in the rice fields from the survey area of Northeastern Uttar Pradesh whereas this finding collaborates with recording similar type of 14 insect pests species. Such similar type insect pests are found by Mohapatra et al. (2013) and find out related damage patterns as present in this study.

6. CONCLUSION AND RECOMMENDATION

6.1. Conclusion

From the study, it shows great diversity of insect pests in paddy ecosystem. It composition includes 14 insect pest species were founded that belongs to 12 families of eight orders. *Hieroglyphus banian* was dominant species among all stages, followed by *Nilaparvata lugens, Leptocoris aacuta, Dicladispa armigera, Cnaphalocrosis medinalis, Stenchaetothrips bioformis, Spodoptera mauritia* pests were found in both varieties of paddy plant. Most abundantly pests which were found in all stages of plant of both varieties were Orthoptera, followed by Homoptera, Hemiptera, Heteroptera, Lepidoptera, Coleoptera, Thysanoptera and Diptera. Six damage patterns were caused by the insect pests in which most of them were leaf cutter or leaf miner followed by Sap sucker, Stem borer, Panicle cutter, Immature grain milk sucker and leaf roller. The periodic abundance of insect pest was seen more in afternoon rather than morning and evening. The Shannon-Weiner Diversity Index calculation shows more diverse pests in the SM variety of paddy than JM variety. Similarly, The Pileou's Evenness is also seen more Even distribution of pest species in SM than in JM variety. SM variety possesses more losses in the quantity than JM variety as SM variety possesses more abundance and diverse pest. It had seen that mostly more pest attack is during grain-filling stage in September than others. It also had shown more diverse of insect pests during afternoon period than evening and morning. This study helps to know about major insect pests found in paddy crop, damage patterns and their periodic abundance in sub-tropical region where climate is humid and hot temperate that provides appropriate strategies for controlling insect pests at specific growth stages of crop.

6.2. Recommendation

- Biological and ecological studies of the pest should be done.
- Laboratory diagnosis of the pests should be done to understand their feeding behaviors and physiological aspects.
- Cropping alternation/or rotation should be done to control the pest damage in the paddy crops instead to minimize the excess application of chemical pesticides.

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List of appendices

Appendix I: Periodic abundance of the pests

Insect pests	Morning time (08:00 to 10:00)	Afternoon time (12:00 to 2:00)	Evening time (4:00 to 6:00)
Hieroglyphus banian	5	28	17
Hysteroneura setariae	7	23	14
Orseolia oryzae	2	12	3
Leptocorisa acuta	8	29	18
Dicladispa armigera	11	32	21
Stenchaetothrips bioformis	5	18	11
Scotinophara coarctata	1	7	3
Nilapravata lugens	10	22	15
Nymphula depunctalis	0	5	1
Scirphophaga incertulas	4	17	9
Brevennia rehi	10	25	16
Cnaphalocrosis Medinalis	1	8	3
Spodoptera mauritia	0	4	1
Nephotettix virescens	12	28	18

Appendix II: Some photographs of Insect pests and field sites during study period