INSECT PESTS OF SAL (*Shorea robusta*) AND PLANTED TEAK FOREST (*Tectona grandis*) OF MORANG DISTRICT, EASTERN NEPAL.

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A thesis submitted in partial fulfillment of the requirements for the award of the degree of Master of Science in Zoology with special paper Entomology.

Submitted to

Central Department of Zoology

Institute of Science and technology

Tribhuvan University

Kathmandu, Nepal

August, 2022

DECLARATION

I hereby declare that the work presented in this thesis entitled "**Insect Pests of Sal (*Shorea robusta*) and Planted Teak Forest (*Tectona grandis*) of Morang District, Eastern Nepal**" 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).

Date: 26, August 2022

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RECOMMENDATION

This is to recommend that the thesis entitled **"Insect Pests of Sal (*Shorea robusta*) and Planted Teak Forest (*Tectona grandis*) of Morang District, Eastern Nepal"** has been carried out by Mr. Shiva Rajbanshi for the partial fulfillment 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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LETTER OF APPROVAL

On the recommendation of supervisor Prof. Dr. Prem Bahadur Budha, Central Department of Zoology, Tribhuvan University, this thesis submitted by Mr. Shiva Rajbanshi entitled **"Insect Pests of Sal (*Shorea robusta*) and Planted Teak Forest (*Tectona grandis*) of Morang District, Eastern Nepal"** is approved for the examination and submitted to the Tribhuvan University in partial fulfillment of the requirements for Master's Degree of Science in Zoology with special paper Entomology.

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CERTIFICATE OF ACCEPTANCE

This thesis work submitted by Mr. Shiva Rajbanshi entitled **"Insect Pests of Sal (*Shorea robusta*) and Planted Teak Forest (*Tectona grandis*) of Morang District, Eastern Nepal"** has been accepted as a partial fulfillment for the requirement of Master's Degree of Science in Zoology with special paper Entomology.

EVALUATION COMMITTEE

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ABBREVIATIONS

CDZ	Central Department of Zoology
CDZMTU	Central Department of Zoology Museum Tribhuvan University
DSM	Direct Search Method
FAO	Food and Agriculture Organization
GPS	Global Positioning System
KSFA	Kanepokhari Sub-division Forest Area
TU	Tribhuvan University

ABSTRACT

Forest of Nepal provides luxurious microclimatic gradients for various species of forest insect pests which are the most pervasive and important agents of forest degradation. The objective of the study was to record the insect pests of major timber trees species with their damage patterns and seasonal variation. Insects were recorded from 7 plots (10 m × 10 m) with 4 light traps along the north–south line transects within Kanepokhari Subdivision Forest Area on east west highway, eastern Nepal during pre-monsoon (May-June) and monsoon (July-August) season in 2021. Direct search method, sweeping, vegetation beating and light trap were used for the collection of the insects in both natural Sal forest and Teak plantation. All together 68 species were recorded including defoliator insects (47 species) were higher followed by woodborers (10 species), sap suckers (9 species), seed borer (1 species) and leaf roller (1 species) belonging to 25 families of 6 orders Coleoptera, Lepidoptera, Hemiptera, Orthoptera, Hymenoptera and Isoptera. This study shows that forest insect pest species diversity (2.93) and evenness (0.73) was slightly higher during monsoon season than pre-monsoon (H'- 2.76 and J- 0.69) season. The diversity of insect pest species was higher in natural Sal forests (pre-monsoon-2.81 and monsoon-3.07) than in Teak plantations (pre-monsoon-1.62 and monsoon-1.53). The findings of this study will provide the baseline information for the future insect pest studies and highlight the importance of immediate intervention by sustainable forest management activities.

1. INTRODUCTION

1.1 Background

Insects are the most diverse group of organisms, with an estimated five million undescribed species (Groombridge et al. 2002) and one million described species that can be found on almost all habitats (Hodkinson & Casson 1991, Brusca & Brusca 2003). They play a crucial part in ecosystem processes and food web interactions (Price et al. 2011). A variety of insects play important roles in maintaining and strengthening ecological processes, including pollination, pest control, degradation, and wildlife conservation (Losey & Vaughan 2006), and ecosystem functions include seed spreaders, herbivores, predators, parasitoids, microbiological feeders, and ecosystem engineers (Weisser & Siemann 2013). They are indispensable additives of healthy forest ecosystems as they assist to decompose and recycle nutrients, construct soils and keep genetic variety inside tree species (Black 2005). Forest insects have direct correlation with environmental variability; greater the ecological niches, the greater the number of species (Szujecki 2012). Majority of forest insects are either beneficial or harmful and the harmful insects are termed as pests (Baker 1972, Furniss & Carolin 1977). Insect pests are integral component of forests, that effect on survival and growth of tree and also disturbs the forest ecosystem (Gray 1972) Where plants are the producers and insects are the main consumers (Nair 2007).

Among different types of forest disturbance; land use changes (Foley et al. 2005), air pollution (Kandler & Innes 1995), insect pests and pathogens (Flower & Gonzalez-Meler 2015), climate change (Allen et al. 2010), invasive species (Richardson & Van Wilgen 2004), forest insect pests are one of major cause of its destruction (Canelles et al. 2021). Forest insect pests are the most pervasive and important agents of disturbance in North American forests affecting about 50 times than that of forest fire (Logan et al. 2003). Global data on forest degradation and disturbances show that insect pests impacted more than 85 million hectares of forest, which is greater than the annual 67 million hectares of forest land burned by forest fires (van Lierop et al. 2015). Forest disturbance caused by insects occurs naturally in the forest environment during periodic outbreaks (Raffa et al. 2009) and population density that exceeds the economic threshold, results significant economic losses (Berryman 2012). The diversity of phytophagous insects is abundant in tropical forests (Nair 2007), annual report of insect pest leaf damage in the tropics is 11.1 %, which is higher than the temperate report of 7.1 % (Coley & Barone 1996). Insects have an impact on every stage of the plant, from seed to finished product, ranging from 0% to 100% consumption of plant material (Nair 2007). Phytophagous damage pattern can be classified as external and internal damage (Regupathy et al. 1995). Monitoring the occurrence of forest insect pests offers clues to understand their impacts on the forest ecosystem and develop a sustainable ecosystem management strategy (Choi & Park 2019).

In Nepal, Forest resources need to be prioritized as they are the storehouse of biodiversity, source of many ecosystem services (Shrestha et al. 2010, FAO 2018). Forest occupies 44.74% of the country's area including other wooded land (DFRS 2015) and divided into 35 forest types (Stainton 1972). On the basis of management practices, forests of Nepal are categorized as Government Managed Forest, Leasehold Forest, Community Forest, Religious Forest, Collaborative Forest, Protected Forest, Protected Area, and Private Forest (Tripathi & Adhikari 2021). Approximately, 3.56 million hectare of forests have been estimated potential for community forest in Nepal handed by government for development, conservation and utilization that collectively benefits community and nation (Tamrakar & Nelson 1991). The latest data shows that approximately 1.23 million ha of forests are handed over to 14,431 forest user groups benefiting 1.66 million households by the end of October 2008 (Chaudhary et al. 2009) supporting substantial quality of forest products (Kandel 2007). Sal (*Shorea robusta*) trees are the highly valuable major hardwood for timber productivity among the natural forest (Webb & Sah 2003) and Teak (*Tectona grandis*) among the planted species (Koirala et al. 2021).

Sal is the most important tree species of ecological as well as economic importance (Tiwari 1995). It's lops and tops are very good source of fuel, seed is used in soap making (Joshi et al. 2006), and its leaves are a major source of fodder and are used to make disposal plates in Nepal (Jackson et al. 1994). Sal forests are also important for landscape-level conservation in the Nepalese Terai as they cover a larger proportion of the area outside proposed wildlife corridors under the Terai Arc Landscape program, which provides locals with fodder, firewood, poles, timber, and wild vegetables (ferns, mushrooms, medicinal plants, and so on) (HMGN 2004, Timilsina et al. 2007). The Sal tree is a slow-growing tree whose growth is slowed by insect infestations (Tripathy et al.

2020). Sal entomology has received special attention from the Indian subcontinent, since the inception of forest research in India (Stebbing 1914, Beeson 1941) as it has major pest problems. Among the forest trees, it has the potential to record the highest number of insects (Joshi et al. 2006). It is reported to host 346 insect pest species (Mathur & Singh 1961), out of which 155 attacks on living trees encompass mainly defoliators (114), seed-feeders (19), borers (18), and sap-suckers (4) (Nair 2007). These phytophagous insects cause massive damage to tree health as well as timber quality.

Similarly, teak is a commercial fast growing tree species and mostly planted in the lower altitude regions of Nepal (Malla & Pokharel 2018). It has an attractive natural color and is valuable for high quality furniture and interior finishing one of the most valuable timber trees in Southeast Asia (Thakor et al. 2019, Kenzo et al. 2020). It is reported to host about 174 species of insect pest all over the world (SenSarma & Thakur 1985) which results a loss in increment volume of plants. The effect of invasive insects pest has also serious impact on the both the natural Sal forest and planted teak forest patches of Nepal (Charmakar et al. 2022).

Nepal's forest provides luxurious microclimatic gradients for various genera and species of forest insect pests due to sharp altitudinal variations (Jha 2009). Invasive alien species and the forest pests and pathogens are the major drivers of deforestation and forest degradation (Paudel & Karki 2013). Insects pest are recorded from both planted and natural forest of Nepal (Bista & Thapa 2012, Malla & Pokharel 2018). A big patches of Sal forest was totally defoliated by *Lymantria mathura* in Sindhupalchowk district and leaf gall caused by the insect *Leptocybe invasa* in Banke (Malla & Pokharel 2018). Parajuli et al. (1999) in eastern terai districts Saptari, Siraha, and Udhaypur districts, Amatya (1992) from surkhet district, Amatya (1994) from Tamagadhi, Tarahara, are the different places of Nepal from where forest insect pest are recorded. *Dalbergia sissoo* (White 1985), *Tectona grandis* (Dhakal 2008), *Eucalyptus* sp. (Malla & Pokharel 2018) and *Shorea robusta* (Amatya 1992) are major timber tress studied for the insect pest in Nepal. Department of Forest Research and Survey (DFRS) and FAO mission has documented the serious infection by insect pests and pathogens, still the forest resource assessment of Nepal are unable to capture the information related to forest pests and pathogens as evidence can be taken from the collected data 2010-2014 (Pokharel 2017).

Lepidoptera, Coleoptera, Hemiptera, Hymenoptera, Isoptera, and Orthoptera are major tropical forest insect pests in order of damage they cause (Gray 1972) which are categorized as defoliators, bark borers, wood borers, seedling, twig, and bud pests, piercing/sucking insects and gall makers, leaf eater, sap sucking, stem borers, fruit borer, seed borers on the basis of damage patterns (Stebbing 1914, Beeson 1941). Insects pests are problems for both planted as well as natural tree species in Nepal's forests (Jha 2009). Although numerous published and unpublished literatures exist about the incidental outbreaks of forest pest in Nepal proper checklist of the insect pest species of the specific plant species of forest is lacking. Therefore, this study aims to focus on the insect pest of major timber and other plant species of Kanepokhari Subdivision Forest Area (KSFA). The result obtained from the study will be the baseline information for future study.

1.2 Research Objective

The general objective of this study was to explore insect pest of the Sal forest and Teak plantation within Forest subdivision area of Kanepokhari, Morang, Nepal

The specific objectives were

i. To identify the insect pest species of Sal forest and Teak plantation in Kanepokhari subdivision forest area.
ii. To find the damage patterns of insect pests.
iii. To compare the insect pest abundance in pre-monsoon and monsoon period.

1.3 Significance of study

Kanepokhari Subdivision Forest Area is the portion of Charkose Jhadi forest located in the Morang district of eastern Nepal. It is one of the most popular forest areas of the district in fern production and forest resources. Among different forest disturbances forest insect pest have serious impact in the forest ecosystem and health of the tree (Malla & Pokharel 2018). Trees from both natural and planted forest are under threat to insect pests. Parajuli et al. (1999), Tuladhar (1996a, 1996b), Amatya (1992) and several other literature recorded several insect pest species affecting the major timber tress of Nepal. So, this study helped to identify the insect pest status of KSFA on the major timber trees as forest is facing problems every year due to insect pest damage but proper identification of the insect pests was lacking. Exploration of the forest insect pest from study area helps for the documentation of the diversity on insect pest their damage pattern and seasonal abundance and variation with specific plant species. Final results obtained from this study will be helpful to planners, policymakers, conservations and management of the forest resources.

2. LITERATURE REVIEW

2.1 Forest Insect Pests

Several insect pests found on *Dalbergia sissoo* in Sagarnath, Saptari District, which includes *Plecoptera reflexa*, *Dasychira* sp., *Euproctic* sp., *Dichomeris eridantis*, *Aspidiotus orientalis*, *Perissus dalbergia* and *Cyclotermes obesus* (White 1985), the first most comprehensive report on insect pests of forest plants in Nepal. Despite being one of the most commonly planted trees in Nepal, *D. sissoo* has suffered from a serious die-back problem caused by forest insect pests (Jackson 1987) and total of 23 insects pests belonging to five orders associated with *D. sissoo* listed from Nepal (Thapa 1992) and these are foremost published report on the occurrence of insect pests which gives baseline information about the pest and supports, the forest insects pest problems in Nepal.

Gmelina arborea, a white Teak native to Nepal is consistently affected by larva of Carpenter Worm (*Prionoxystus* sp.), *Dihammus cervinus* (Coleoptera: Cerambycidae), *Calopepla leayana* (Coleoptera: Chrysomelidae) and *Glenea indiana* (Coleoptera: Cerambycidae) which bores into stems of saplings and *Ozola minor* (Lepidoptera: Geometridae), a small moth whose larvae feeds on the leaves (Dhakal 2008), and likewise insect pests reported by (Dhakal 2008) from another non native species of Teak (*Tectona grandis*) were *Hyblaea puera* (Lepidoptera: Hyblaeidae) major defoliator (Bhandari & Bhattarai 2022), leaf/terminal shoot feeding *Helicoverpa armigera* (Lepidoptera: Noctuidae), *Eutectona machaeralis* (Lepidoptera: Pyralidae) *Sahyadrassus malabaricus* (Lepidoptera: Hepialidae) and *Zeuzera coffeae* (Lepidoptera: Cossidae) as stem borer. Malla & Pokharel (2018) recorded that Sal forest was totally defoliated by white moth *Lymantria mathura* in Sindhupalchowk district and leaf gall caused by the insect *Leptocybe invasa* an invasive species in Eucalyptus plantation area in Banke district of Nepal. Amatya (1992) recorded *Hoplocerambyx spinicornis* and *Aularches* sp. as common borer and defoliator respectively on Sal from Surkhet district of Nepal. A curculionidae weevil was reported as a serious *D.sissoo* plant defoliator in Tamagadhi, Tarahara (Amatya 1994).

Three major insect pests: pinhole insects as xylem feeders, heartwood borer destroying the xylem system and termite feeding upon the bark of stems and roots were published first, later a list of 36 insect pests were recorded in *D. sissoo* belonging to orders Lepidoptera, Coleoptera, Orthoptera, and Isoptera by reviewing the published literatures

(Tuladhar 1996a, Tuladhar 1996b). Several species of insect borers of the families Scolytidae, Buprestidae, Cerambycidae beetles were responsible for the die-back of *Dalbergia sissoo* in eastern Terai districts Saptari, Siraha, and Udhaypur (Parajuli et al. 1999). A big patch of Sal Forest was totally defoliated by White Moth (*L.mathura)* in Sindhupalchok district and leaf gall insect *Leptocybe invasa* invasive species on Eucalyptus in Banke district of Nepal (Malla & Pokharel 2018).

Survey conducted on Teak plantation at Konkan region of Maharashtra, India recorded five insect pests as teak leaf Skeletonizer, *Eutoctona machaeralis*; teak defoliator, *Hyblaea puera*; leafhopper, *Coclida* sp., grasshopper and meagre infestation of termites (Dhobe et al. 2012). Pine bark beetles of the genus *Dendroctonus* are the most destructive forest pest in the region wherever native pine forest occur, Among them *D. adjunctus and D. frontalis* are the most destructive one (Billings et al. 2004). A total of 28 species of insect and one species of acarine, covering 24 families and 8 orders are recorded as commonly occurring pests of urban forests in Malaysia (Lovett et al. 2016). Ferrell (1996) concluded that Sierra Nevada forests have high levels of mortality caused by bark beetles infesting trees stressed by drought, fire, overly dense stands, and pathogens. Two insect pests *Lawana conspersa* and *Icerya seychellarum* were found first time among 5 species belonging to Coleoptera, five Lepidopteran species, six Hemipteran species from *sissoo* forest of Jharkhand, India (Kumar 2017).

A total of 155 insect pest species are associated with the living tree out of 346 recorded in the *Shorea robusta* tree, belonging to the orders Lepidoptera (105), Coleoptera (31), Thysanoptera (9), Hemiptera (4), Orthoptera (4), Ephemeroptera (1) and Isoptera (1) (Roychoudhury 2015, Roychoudhury et al. 2018). Among these, the Sal Heartwood Borer (*Hoplocerambyx spinicornis*) commonly known as Sal borer was the most devastating insect pest responsible for catastrophic damage of Sal forests which emerge soon after the onset of monsoon (Kulkarni et al. 2018, Chhetri et al. 2021, Kulkarni & Chander 2022).

2.2 Damage patterns of Insect Pest

Insects pest species are categories mainly as defoliators (114 species), seed feeder (19 species), borers (18 species) and sap suckers (4 species) (Stebbing 1914, Beeson 1941). Forest insect pests associated with living tree encompassing mainly defoliators followed by seed-feeders, borers, and sap-suckers (Joshi et al. 2006). Bark and wood borers feed on phloem and xylem tissue of trees and to locate the most suitable host they follow the blends of volatiles released by stressed trees (Lieutier et al. 2016). Sal sap oozing out from the fall, injured and cut ends of the standing tree attract the heartwood borers (Stebbing 1914, Beeson 1941). Presence of holes and wood dust at the base of the tree are noticeable symptoms of wood boring insect (Roychoudhury 2017).

2.3 Insect Pest Seasonality and Diversity

Increase in food quality, reduces the natural enemy pressure and extended period of favorable weather increase the insect abundance and diversity (Andrewartha & Birch 1986). Severity and occurrence of outbreaks in forest insect pests revealed a mixture of both positive and negative relations between seasonal fall and rise in temperature and precipitation (Haynes et al. 2014). The numbers of phytophagous insects pest species of oak in United Kingdom shows seasonal fluctuation (Southwood et al. 2004). Larva of Lepidopteron insect shows high diversity in wet conditions in Costa Rican dry forest (Janzen 1993). Leal et al. (2016) concluded that the richness, abundance of the forest insects is positively correlated with the tree richness and density. Insects are more active at night in dry as compare to wet season to avoid the harsh condition during day and evergreen trees support greater richness as compared to deciduous trees (Silva et al. 2017).

As Nepal's average annual temperature rises and its rainfall patterns change, it is expected that these changes will definitely have an effect on the frequency and severity of outbreaks of forest insect pests as well as their distribution to new ecological areas. According to Bista & Thapa (2012), precise knowledge about the biology, epidemiology, and potential management strategies of insect pests is necessary for effective pest management; however, only limited qualitative information is available at the local level, and Nepal currently lacks trustworthy quantitative information.

3. MATERIALS AND METHODS

3.1 Study Area

The field survey was conducted in two community forests of Morang district, Province no.1, Nepal viz., Graminsudhar (839.22 ha) and Jana Jagriti (289.68 ha) under Kanepokhari sub-division forest area (026° 65.906'N and 087° 49.71'E). Morang district has both plain terai and hilly landscapes, with a total area of 1,855 square kilometers and a population of 965,370 people (CBS 2011). The district is bounded to the east by Jhapa, to the west by Sunsari, to the north by Dhankuta and Panchthar districts and to the south by Bihar, India. The KSFA is a portion of the Charkose Jhadi forest that lies between Kanepokhari Rural Municipality and Letang Municipality and is bordered by two rivers, the Chisan and the Das khola. The Kanepokhari sub-division forest has an area of 82 square kilometers, with 15 square kilometers of forest dominated by Sal tress. The average annual temperature is 24.60°C, with 2256 mm of precipitation.

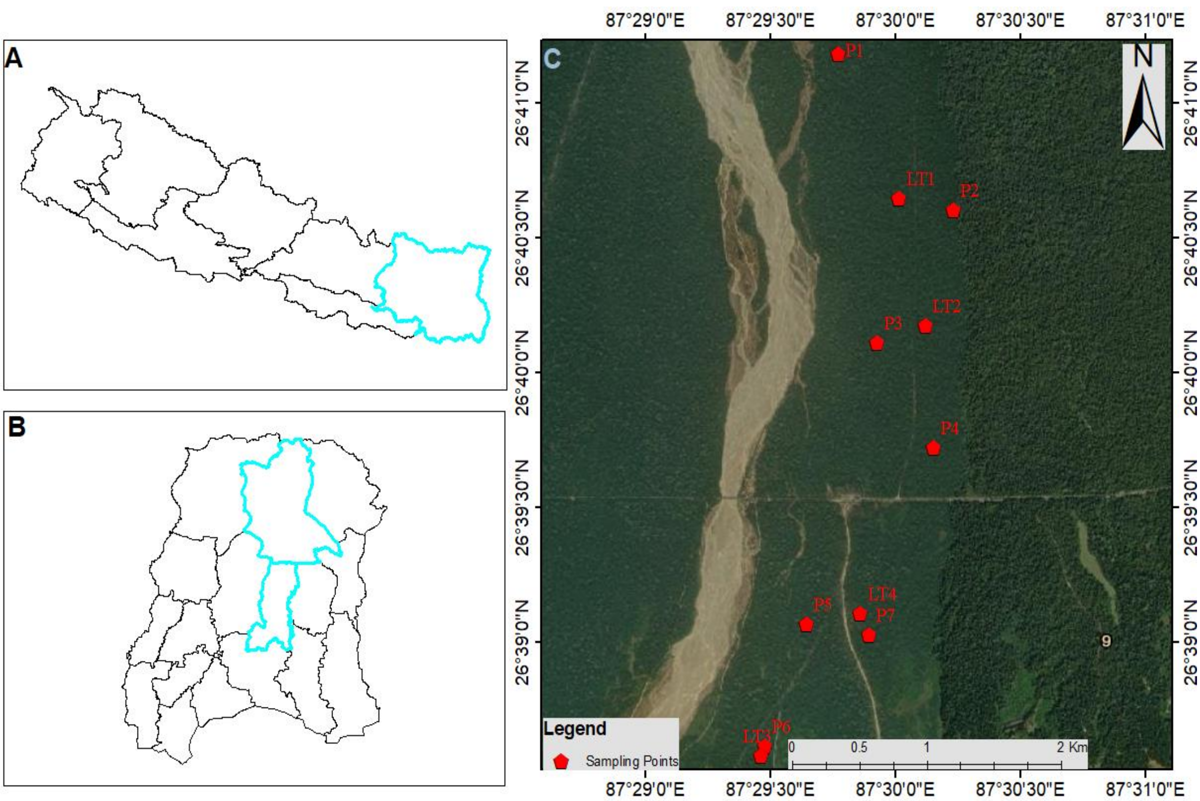

Figure 1. A. Map of Nepal showing province, B. Map of Morang district showing study area, C. Map of Study area showing sampling Points

3.2 Materials

The materials used on the survey were sweeping net (opening diameter of 30cm and 60cm in length), killing bottle, forceps, absolute alcohols, ethyl acetate, insect pins, insect box, naphthalene balls, plastic vials, lead pencil, white cloths, light bulb, inverter and measuring tape.

3.3 Methods

3.3.1 Sampling Methods

Sampling Design

For sample collection, approximately five km of N-S road transects perpendicular to the EW highway (Three km long transect toward the north of the highway and two km long transect toward the south of the highway) were chosen. In total, seven 10x10 m sampling plots were laid alternately toward the east and west along the N-S Kanepokari – Letang and Kanepokhari – Rangeli roads, a distance of 800 meters. The physical features of the plot were, it most consist maximum number of Sal tree on natural Sal forest whereas Teak plant on planted Teak forest and minimum distance from the road must be 100 m.

P1, P3 and P5 in Jana Jagriti community forest, P2, P4 & P7 in Gramin Sudhar community forest, and P6 in teak plantation under Jana Jagriti community forest area were selected alternately based on the road transect. In both seasons, samples were collected once a week for two weeks in each plot between 10:00 A.M. and 5:00 P.M. using various survey methods like direct search method, beating, and sweeping approximately two hour in each plot to capture different types of insect pests as a combination of traps gives better species richness data (Noyes 1989). The soil dwelling insects were not collected during the sample collection.

Both community forests had two night time moth traps set up, L1 (Sal forest) & L3 (Teak plantation) on Jana Jagriti community forest and L2 & L4 (Sal forest both) on Gramin Sudhar community forest. Unless there were logistical or weather issues, each location was sampled for two nights from 6:30 p.m. to 11:30 p.m. (May to August). Standardized trap designs were not achievable due to a lack of equipment. Insects were collected from May to August 2021 covering Pre-monsoon and Monsoon seasons. GPS location, collected date and collection method of the collected sample from each plot was noted. Canopy height was measured by tangent method (Korning & Thomsen 1994) with the help of paper clinometers and other environmental variables like herb cover, shrub cover and canopy cover was estimated visually by dividing the plot into four sub-quadrates from each corner of the plot.

Pest Detection

Not all insects are pest. Insect pests were detected in the field through visual observation. All insects (adult, juvenile, larval stages etc.) were carefully observed with their feeding habits. Any insect feeding on the leaf was recorded, damage pattern was noted, any sign or mark (dust, holes, frass) were noticed, and their relative damage was assessed. If larval stages feeding on leaves were found and they were reared in room temperature to identify the adult stage of pest and pest insects which were not seen damaging in the field, their pest status was confirmed using secondary references.

Sample Collection

Direct Search

Hand collection was done by direct observation on each plot using the 'one man, one hour' search method (Khairmode & Sathe 2014) from each plot's four corners. This method included searching for defoliator and leaf rolling insects on the leaves, seed borer insects inside the seeds, and wood borer insects by pulling off loose bark with forceps and chopping the damaged branches.

Beating

The beating and jerking method (Tripathy et al. 2020) was used to collect insects hiding under foliage and tree branches. Pole size plants were beaten by a hand stick and falling insects were collected with the forceps and brush. A white cotton sheet or umbrella was used as per feasibility.

Sweeping

A sweeping net was used to sweep each quadrate. Ten sweeps were performed at once to determine a sweeping unit, and each plot received a total of five sweeps, which were repeated after a 10-minute interval (Kumar & Naidu 2010). This method was used to catch active fliers.

Light Trap

Two light sources from opposite directions were reflected onto a single six feet white vertical screen placed 1ft above ground level for the trap. For the light sources, a portable solar power inverter was used to provide electricity to 18 watt LED bulb and 100 watt filament bulbs that were hung on the opposite side of the vertical screen for around four to five hour per night (from 6:30 to 11:30 P.M.). Every half-hour, the trapping site was visited for the collection of the moths. Moths on the white screen (cotton sheet) were collected using a killing jar, while flying moths was collected using a sweeping net around the site.

3.3.2 Identification of the Specimens

The collected specimens were brought to Entomology Laboratory of Central Department of Zoology, Kirtipur. The specimens were sorted and identified up to the family level by using the key from book (Triplehorn & Johnson 2005) and further identification was done as per the relevant literature and taxonomic keys (Beeson 1941, Haruta 1992,1993,1994,1995, and 1998, Basnet 1999, Haruta 2000, Kalleshwaraswamy et al. 2013, Slipinski & Escalona 2013, Thapa 2015, Sultana et al. 2017, Legalov 2020). Reference specimens of identified pests were pinned with entomological pins in entomological boxes. These specimens were then deposited in the Central Department of Zoology Museum of Tribhuvan University (CDZMTU), Kirtipur, Nepal.

3.4 Data analysis

Margalef's richness index, Shannon-Wiener diversity index and Pielou’s evenness index was used for studying the species richness, diversity and evenness of forest insect pests using R-software (R-Core-Team 2022) and polynomial regression was performed by using Past software.

4. RESULTS

4.1 Forest Insect Pest Species

A total of 1392 individuals of forest insect pests belonging to 68 species from six orders and 25 families were recorded from seven sample plots and four light traps in pre-monsoon and monsoon surveys (ANNEX-2). Among the 68 species, 28 species belong to the order Lepidoptera, followed by 18 species of Coleoptera and nine species of Hemiptera and Orthoptera. Each order Hymenoptera and Isoptera Contained only two species (Fig.2). However, the most abundance species belong to Isoptera (31%), and Hymenoptera (22%) (Fig.3).

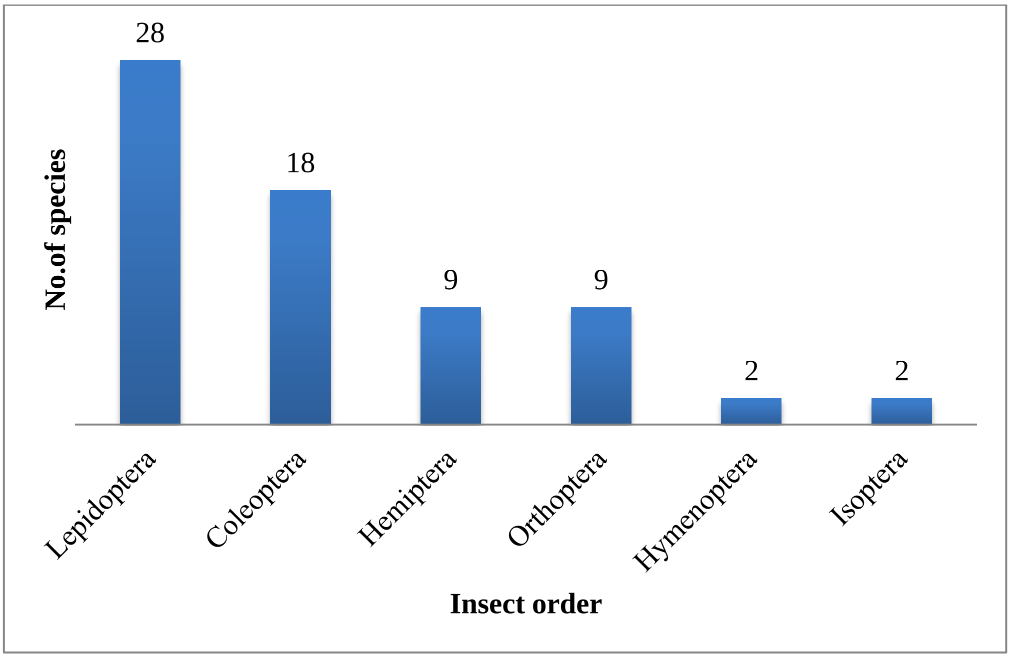

Figure 2. Richness of insect pests based on orders

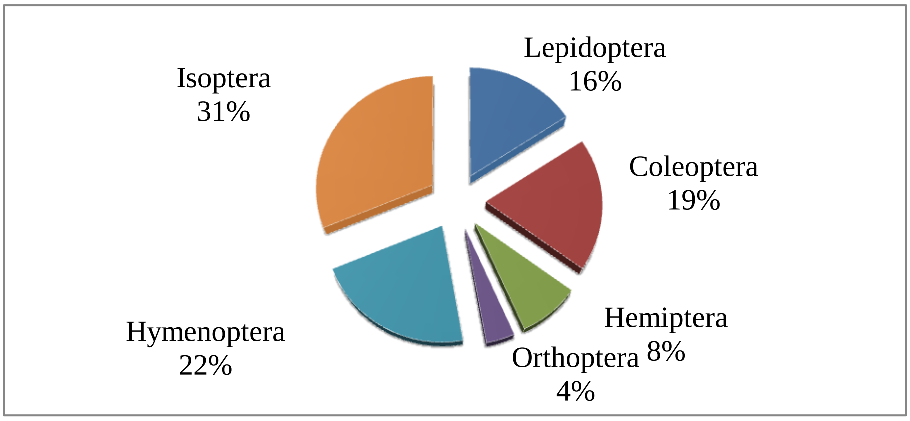

Figure 3. Abundance of forest insect pest based on orders

The comparative species diversity of pre-monsoon and monsoon season varies from 7-18 and 7 -15 respectively. However, the abundance of insect species in the respective seasons includes 71 to 113 for pre-monsoon and 56 to 116 in monsoon season. The overall Shannon-Weiner diversity index was H'=2.30 in pre-monsoon and H'=2.46 in monsoon season. The plot wise diversity index varies from 1.10 to 2.30 in pre-monsoon and 1.80 to 2.46 on monsoon season (Table 1 and Table 2).

Table 1. Diversity indices of insect pest collected from sample plots in pre-monsoon.

Indices	**Plot1**	**Plot 2**	**Plot 3**	**Plot 4**	**Plot 5**	**Plot 6**	**Plot 7**	**Overall**
Abundance	84	87	91	71	80	113	84	610
Richness	18	12	11	15	14	7	14	32
Shannon Diversity Index (H')	2.30	1.78	1.57	1.98	1.78	1.10	1.741	2.30

Table 2. Diversity indices of insect pest collected from sample plots in monsoon.

Indices	**Plot 1**	**Plot 2**	**Plot 3**	**Plot 4**	**Plot 5**	**Plot 6**	**Plot 7**	**Overall**
Abundance	95	65	64	56	78	116	91	565
Richness	15	13	13	12	15	7	15	31
Shannon Diversity Index (H')	2.01	1.80	1.83	2.27	2.30	1.09	1.99	2.46

4.1.1 Insect Pest Species Recorded in *Shorea robusta* and *Tectona grandis* of KSFA

A total of 20 species were identified as pests of major timber trees i.e. Sal and Teak among collected Insect pests.

Table 3. Insect pest incidences during pre-monsoon and monsoon periods in natural Sal tree and planted Teak at KSFA, Morang district, 2021

Insect pest	**Damage parts**	**Damage patterns**	**Plant species**	**Pest detection**
Myllocerus sp.	leaves	Defoliator	Both Sal and Teak	(Paunikar 2015, Roychoudhury 2015, Patil et al. 2016)
Hypomeces squamosus	leaves	Defoliator	Teak and *Bombax ceiba*	DO and UK 2014
Ectropis bhurmitra	leaves	Defoliator	Both Sal and Teak	(UK 2014)
Conogethes punctiferalis	leaves	Defoliator	Both Sal and Teak	Inoue & Yamanaka 2006 and Robinson et al. 2010
Adelocera sp.	bark	Stem borer	Both Sal and Teak	Patil et al. 2016 and DO
Camponotus sp.	Bark	wood borrowing to expands nesting site	Both Sal and Teak	DO and Akre et al. 1995
Odontotermes obesus	Bark	external mud galleries and galleries under stem	Both Sal and Teak	DO, Tripathy et al. 2020, Shanbhag & Sundararaj and Rasib et al. 2014
Coptotermes sp.	Bark	external mud galleries and galleries under	Teak	DO and Costa et al. 2020

		stem		
Hieroglyphus sp.	leaves	Defoliator	Teak	DO and Roychoudhury et al. 2003
Lamida sp.	leaves	Defoliator	Sal	DO, Rearing and Roychoudhury 2015
Macalla sp.	leaves	Defoliator	Sal	DO and Rearing
Arctonis sp.	leaves	Defoliator	Sal	DO and Rearing
Achaea janata	leaves	Defoliator	Sal	Roychoudhury 2015 and Robinson et al. 2010
Conogethes evaxalis	leaves	Defolaitor	Sal	Roychoudhury 2015
Pammene sp.	leaves	Seed borer	Sal	Rearing
Acrida sp.	leaves	Defoliator	Sal	DO and Roychoudhury 2015
Physopelta schlanbuschi	Leaves	Sap sucking	Sal	DO and Basnet 1999
Hoplocerembyx spinicornis	Wood	Wood borer	Sal	DO and Roychoudhury 2015
Xylotrechus sp.	Wood	Wood borer	Sal	Khatua 1996
Agrypnus sp.	Bark	Stem borer	Sal	DO, Basnet 1999

4.2 Damage Patterns of Forest Insect Pest Based on Feeding Behavior

The abundance of defoliator species was greatest, followed by sap suckers, wood boring insects, mud galleries (leaf rollers), and seed borers (Fig. 4). Similar to the outcome of richness, the abundance of defoliator insects was higher (n = 483), followed by mud galleries generating insects (n = 434), leaf rollers (n = 202), wood borers (n = 156), sap feeders (n = 116) and seed borers (n = 116), with a single record of a seed borer from the entire study.

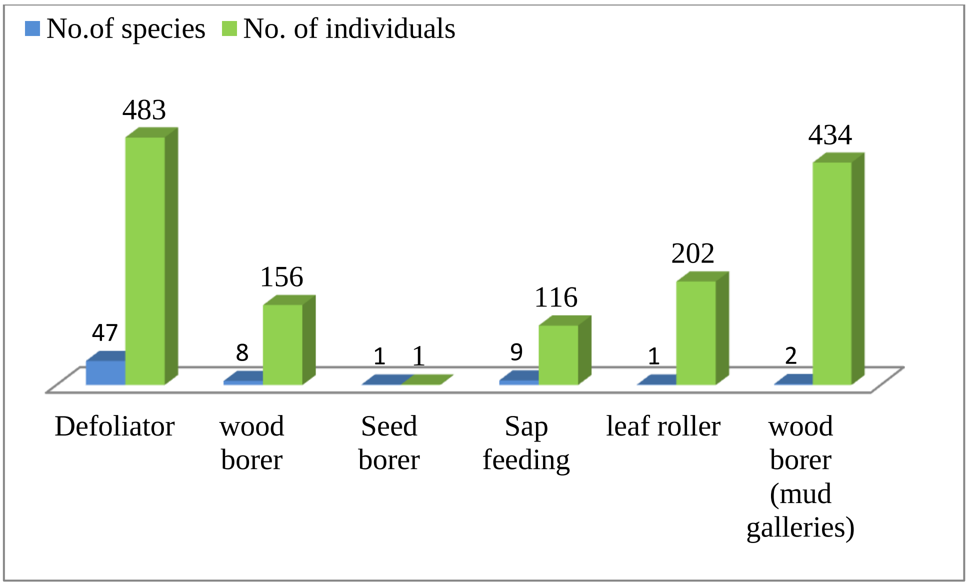

Figure 4. Richness and abundance of insect pest based on damage type

4.3 Insect Pest Abundance in Pre-monsoon and Monsoon Period

Among the insect pests collected throughout the sampling period, the overall diversity of pre-monsoon was slightly lower (H' = 2.76) than that of monsoon (H' = 2.93). The insect pests were evenly distributed in the monsoon season (J = 0.73) as compared to the pre-monsoon (J = 0.69) and higher abundance of insect pests was found in pre-monsoon than in the monsoon (Table 4). In natural Sal forest, a similar type of result was seen with higher diversity in monsoon (H' = 3.07) than in pre-monsoon (H' = 2.81) but the diversity of insects in teak plantation was more in pre-monsoon (H' = 1.62), which is slightly more than in monsoon (H' = 1.53) (Table 4).

Table 4. Insect pest in pre-monsoon and monsoon of Sal forest and planted Teak forest

Indices	**Pre-monsoon**	**Monsoon**	**Natural Sal forest**		**Teak Plantation**	
			Pre-Monsoon	Monsoon	Pre-monsoon	Monsoon
Abundance	710	682	578	549	132	133
Richness	56	56	54	54	15	13
Shannon Diversity Index (H')	2.76	2.93	2.81	3.07	1.62	1.53
Evenness (J)	0.69	0.73	0.74	0.77	0.59	0.59

The diversity of insect pests was highest in Sal forest (pre-monsoon: Day H' =2.36, night H' =2.72 and Monsoon: Day H' =2.59, night H' = 2.61) than in Teak plantation (pre-monsoon: Day H' =1.09, night H' =1.91 and Monsoon: Day H' =1.09, night H' = 0.99) (Table 5).

Table 5. Insect pest in pre-monsoon and monsoon of Sal forest and Teak plantation based on trapping method.

Indices	**Pre-monsoon (Day)**		**Pre-monsoon (night)**		**Monsoon (Day)**		**Monsoon (night)**	
	Sal forest	Teak plantation	Sal forest	Teak plantation	Sal forest	Teak plantation	Sal forest	Teak plantation
Abundance	497	113	81	19	449	116	100	17
Richness	31	7	23	8	30	7	24	6
Shannon Diversity Index (H')	2.36	1.09	2.72	1.91	2.59	1.09	2.61	0.99
Evenness (J)	0.68	0.56	0.87	0.92	0.76	0.56	0.82	0.55

4.4 Relationship of Insect Pest and Environmental Variables

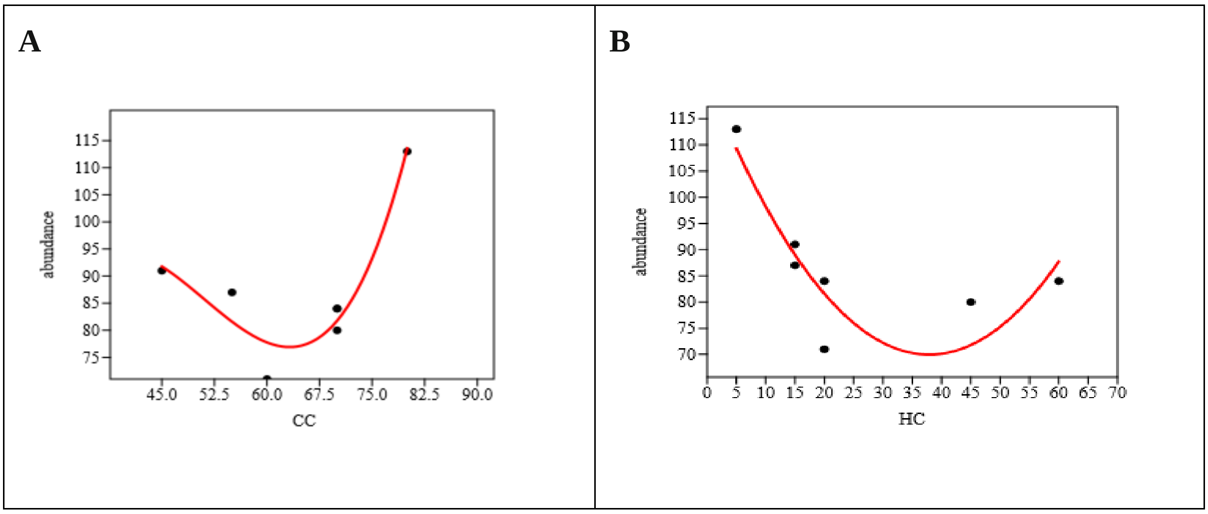

Figure 5. A polynomial regression analysis of abundance, with canopy cover, B. abundance with herb cover.

Table 6. Polynomial regression of No. of individuals with canopy cover and herb cover in pre-monsoon season

Regression	Canopy cover	Herb cover
First order r^2	0.127	0.21
AIC	892.7	799.48
Second order r^2	0.854	0.78
AIC	161.71	235.04
Third order r^2	0.91	0.88
AIC	116.93	139.7

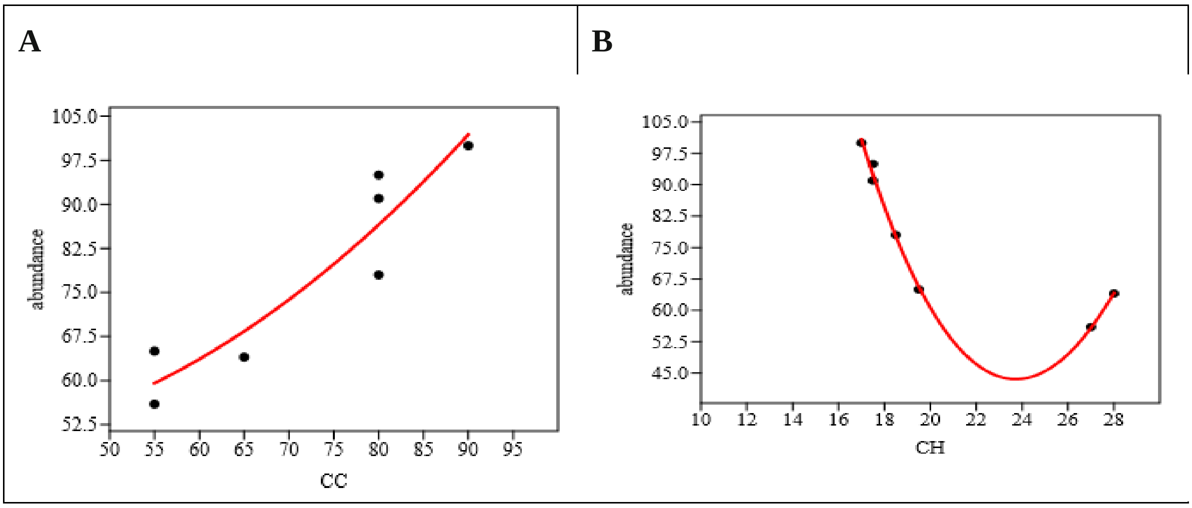

Figure 6. A polynomial regression analysis of abundance, with canopy cover, B. abundance with canopy height

A polynomial regression analysis of number of individuals, with canopy cover, and canopy height is shown in table 9 and figure 5 (A and B). Canopy cover better suited to the second order ($p<0.05$) and canopy height was better suited to the third order ($p < 0.05$) in monsoon season.

Table 7. Polynomial regression of No. of individuals with canopy cover and canopy height in monsoon season

Regression	**Canopy cover**	**Canopy height**
First order r^2	0.86	0.678
AIC	252.25	581.67
Second order r^2	0.87	0.9941
AIC	243.58	24.53
Third order r^2	0.88	0.994
AIC	226.5	38.01

5. DISCUSSION

This study explored the diversity of insect pest along the N-S road transects perpendicular to the E-W highway of KSFA, Morang district. A total 1392 individuals belonging to 25 families were recorded as pest from two seasons (pre-monsoon and monsoon). From the seven sampling plots and four light traps, 68 genera of insect pests were identified as pests. Collected insect pests were classified as defoliators, seed borers, wood borers, sap suckers, leaf rollers and mud galleries (inside as well as outside of the bark) on the basis of their feeding behavior as suggested by Stebbing (1914) and Beeson (1941). Defoliator insect pest species were recorded maximum in KSFA, which is consistent to many other studies like pest of *D. sisso* by (Kumar 2017) and insect pests of *Shorea robusta* by (Roychoudhury 2015). Among the collected insect pests, 17 species were recorded as insect pests of *S. robusta* which is maximum than others as it comprises maximum number insect species among the forest trees (Mathur & Singh 1960, Roychoudhury 2015, Roychoudhury et al. 2017) as carrying capacity increases with increase in the size of tree. Guedes et al. (2000) supports, the result as the size of *S. robusta* is comparatively greater. Previous studies (Bista & Thapa 2012, Kulkarni & Chander 2022) conclude *Hoplocerembyx spinicornis* as the major heartwood borer of *S. robusta.* Same result was found from this study as well and other pests are *Achaea janata*, *Conogethes evaxalis*, *Acrida* sp. as defoliator (Roychoudhury 2015), *Xylotrechus* sp. as wood borer (Khatua 1996), and *Pammene* sp. as seed borer (Choubey et al. 2004). Further, *Lamida* sp., *Macalla* sp., *Arctonis* sp., was identified as defoliator pests by direct observation and rearing the larvae.

Similarly, *Myllocerus* sp. as defoliators and *Odontotermes obesus.* as major wood borer forming mud galleries were observed during survey on both Sal and Teak plantations, which were already recorded as the pests of Sal (Tripathy et al. 2020) and Teak (Rasib et al. 2014, Patil et al. 2016). Costa et al. (2020) listed *Coptotermes tastaceus* as heartwood termites, which forms external and internal galleries affecting wood, similar infestation was observed during the survey. *Adelocera modesta*, an elaterid beetle as a rare pest damaging stems on *Tectona grandis* was recorded by (Patil et al. 2016), this reference supports to categories *Adelocera* sp. as pest of Sal and Teak collected by direct observation method from the inner layer of stem. In the same manner (Basnet 1999) reported *Agrypnus* sp. as pest of Sal which was observed in this study as well and conformed by direct observation on the field. Furthermore, information of collected forest insect pest species, their collection method, damage type, host plants and conformation method as pest is highlighted on Appendix 1.

The presence of holes and wood dust at the base of the tree were noticed to identify the pest on the field by direct observation as suggested by (Roychoudhury et al. 2017). Similarly larva feeding on the leaves, seed was observed carefully during the field observation to categories them as pest. Lieutier et al. (2016) showed positive relation between blends of volatile released by the stress trees and abundance of the borer insects which supports the finding of this study that the abundance of bark and wood borer insect on stressed Sal tree were recorded higher as the availability of insect increases with the suitable breeding material (Rudinsky 1962, Lekander et al. 1977). Among the environmental variables the abundance of observed species on both pre-monsoon and monsoon were significant with canopy coverage which was also observed by (Peltonen et al. 1997) on their survey, as higher canopy cover has positive correlations with the diversity of insect pest (Basset et al. 2003, Neves et al. 2013). Host plant size leads higher diversity of sap-sucking and chewing insects as they offer greater availability of resources to hervivorous insects (Stiling & Moon 2005, Neves et al. 2013). This result differ in plot diversity and abundance unless the natural obstacles were there like rainfall during our survey.

The study conclude pest abundance higher in pre-monsoon than in monsoon, this might be due to the disturbance during field survey because of rainfall but insect pest species evenness and diversity was high during monsoon (J=0.67, H'=2.93) than in the pre-monsoon season (J=0.73, H'=2.76) that attributed to abundant resources of food for herbivores on monsoon, which vary seasonally with change in environmental conditions (Wolda 1978). In this study moth species recorded abundant in monsoon as Lepidoptera species are phytophagous which possess strategies to survive like larval and pupae diapauses, with emerging out in rainy season (Janzen 1987, Aiello 1992) and availability of new highly nutritious young leaves throughout the rainy season (Pontes Ribeiro & Basset 2007, Neves et al. 2014). In case of the insect pest collected from light trap, the abundance was higher on monsoon as (Guedes et al. 2000) concluded abundance of nocturnal insects was higher in monsoon season. It is due to fact that abundance of nocturnal insects in wet climatic conditions (Frith & Frith 1985). Diversity and abundance of sap sucking insects are found high in monsoon season as compared to pre-monsoon similar result was recorded by (Tripathy et al. 2020). New leaves generally have lower toxin levels, are softer, have higher nutrient content (Feeny 1970) which are more suitable for sap feeders supports the results and similar finding was observed by (Ott et al. 2006).

Kulkarni et al. (2018) concluded larvae of *H. spinicornis* begin boring soon after hatching from July to April, which supports the obtained result that the abundance of Sal major heartwood borer in the monsoon season were high as it's life cycle coincides with the start of the monsoon. Similarly, Isopteran wood boring insects abundant during wet conditions (Mbah 2010) support abundance in the monsoon. Peltonen (1997) found habitat type has significance role in insect abundance as plant and insects interact by the way of mutualism and phytophagy (Gaston 1991, Okrikata & Yusuf 2016) so, insect pest species richness was higher in natural Sal forest than Teak plantation.

6. CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The survey recorded 68 pest species from 25 families, revealing slightly higher diversity during the monsoon season than that of pre-monsoon and the diversity of insect pest was higher in natural Sal forest than in Teak plantation. Species richness of defoliator insects was highest, followed by wood borer, sap suckers, seed borer and leaf roller. Out of 68 species 20 insect pest species including *Myllocerus* sp., *Ectropis bhurmitra*, *Conogethes punctiferalis*, *Adelocera* sp., *Camponotus* sp., and *Odontotermes obesus* were common on both Sal and Teak plant respectively. The *Hoplocerembyx spinicornis* on Sal and *Odontotermes obesus* on both Sal and Teak plants were the two most serious pests out of all those found. Since Nepal has a wide variety and a large number of forest insect pests, these findings may be helpful for comprehensive conservation efforts to stop further invasions.

6.2 Recommendations

- Further study in Sal forest and Teak plantation in other areas are needed to find other pest species.
- Damage Assessment of Sal Heartwood Borer and other species pest of Sal and Teak are needed to explore from other part of the country.
- Study on the life cycle, behavior and ecology of forest insect pests should be done to understand their reproduction patterns, feeding habits, host preferences, and interactions with other organisms in the forest ecosystem.

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APPENDICES

Appendix 1: Checklist of Forest Insect Pest of Kanepokhari Sub-division Forest Area.

Taxa	Family	Collection method	Damage type	Host plant	Confirmation method
Coleoptera					
Epilachna dumerili	Coccinellidae	D.S.M, Sweeping & Beating	Defoliator	Karam tree, Ranabas and *Stereospermum suaveolens* (Pithari)	DO and Basnet 1999
Hoplasoma unicolor	Chrysomelidae	D.S.M, Sweeping & Beating	Defoliator	*Clerodendrum sp*.	DO and (Bhumannavar 1991)
Pseudocophara bicolor	Chrysomelidae	Sweeping and beating	Defoliator	unknown	DO
Heterapsis dillwyni	Chrysomelidae	Beating	Defoliator	Sindure	DO
Aulacophora sp.	Chrysomelidae	Sweeping and beating	Defoliator	unknown	(Rashid et al. 2014)
Chrysolina sp.	Chrysomelidae	Sweeping	Defoliator	weeds	(Adair & Edwards 1997)
Myllocerus sp.	Curculionidae	DO and beating	Defoliator	Sal and teak	DO, (Paunikar 2015, Roychoudhury 2015, Patil et al. 2016, Tripathy et al. 2020)

Tanymecus sp.	Curculionidae	Beating	Defoliator	unknown	(Neelima 2013)
Hypomeces squamosus	Curculionidae	DO and beating	Defoliator	Teak and *Bombax ceiba*	(UK 2014)
Sitona sp.	Curculionidae	Sweeping	Defoliator	unknown	(El-Bouhssini et al. 2008)
Naupactus sp.	Curculionidae	Sweeping	Defoliator	unknown	(Logan et al. 2008)
Hoplocerembyx spinicornis	Cerambycidae	D.S.M	Wood borer	Sal	DO and (Roychoudhury et al. 2018)
Xylotrechus sp.	Cerambycidae	D.S.M	Wood borer	Sal	(Khatua 1996)
Apriona sp.	Cerambycidae	D.S.M	Wood borer	unknown	(Ji et al. 2011)
Philanthaxia sp.	Buprestidae	Sweeping	Wood borer	unknown	
Agrypnus sp.	Elateridae	D.S.M and light trap	Wood borer	Sal	DO and Basnet 1999
Adelocera sp.	Elateridae	D.S.M	Wood borer	Sal and Teak	DO and
Dicronychus sp.	Elateridae	D.S.M	Wood borer		DO
Lepidoptera					
Lamida sp.	Pyralidae	D.S.M	Defoliator	Sal	DO, Rearing and (Roychoudhury 2015, Patil et

					al. 2016)
Macalla sp.	Pyralidae	D.S.M	Defoliator	Sal	DO and Rearing
Arctonis sp.	Erebidae	D.S.M and light trap	Defoliator	Sal	DO and Rearing
Artena dotata	Erebidae	Light trap	Defoliator	unknown	(Singh et al. 2019)
Thyas coronata	Erebidae	Light trap	Defoliator		(Singh et al. 2019)
Parasa argentilinea	Erebidae	Light trap	Defoliator	Mango and Ficus tree	(Robinson et al. 2010)
Scopelodes testacea	Erebidae	Light trap	Defoliator	Musa sps.	(Robinson et al. 2010)
Achaea janata	Erebidae	Light trap	Defoliator	Sal and Acacia	(Robinson et al. 2010, Roychoudhury 2015)
Conogethes evaxalis	Crambidae	Light trap	Defoliator	Sal	(Roychoudhury 2015)
Conogethes punctiferalis	Crambidae	Light trap	Defoliator	Sal and Teak	(Inoue & Yamanaka 2006, Robinson et al. 2010, Roychoudhury 2015)
Herpetogramma phaeopteralis	Crambidae	Light trap	Defoliator	grasses and foliage	(Korndorfer et al. 2004)

Agroter ascissalis	Crambidae	Light trap	Defoliator	unknown	(Chen et al. 2017)
Eoophyla peribocalis	Crambidae	Light trap	Defoliator	aquatic vascular plant and ornamental plants	(Yen 2004)
Talanga sexpunctalis	Crambidae	Light trap	Defoliator	Sapling of Ficus tree	(Libra et al. 2019)
Glyphodes bicolor	Crambidae	Light trap	Defoliator	Ficus tree	(Robinson et al. 2010, Chaovalit & Pinkaew 2020)
Palpita argentilinea	Crambidae	Light trap	Defoliator	unknown	(Kumral et al. 2007)
Paranacoleia lophophoralis	Crambidae	Light trap	Defoliator	unknown	
Ectropis bhurmitra	Geometridae	Light trap	Defoliator	Sal and Teak	(UK 2014, Roychoudhury 2015)
Biston suppressaria	Geometridae	Light trap	Defoliator	Acacia and *Bombax ceiba*	(Robinson et al. 2010)
Comostola laesaria	Geometridae	Light trap	Defoliator		(Nayanathara & Narayana 2022)
Thalassodes antiquadraria	Geometridae	Light trap	Defoliator		(Kannan & Rao 2006)
Geometrid unknown 1	Geometridae	Light trap	Defoliator		
Geometrid unknown 2	Geometridae	Light trap	Defoliator		

Episparis liturata	Noctuidae	Light trap	Defoliator		(Robinson et al. 2010)
Noctuid unknown 1	Noctuidae	Light trap	Defoliator		
Cyclidia substigmaria	Drepanidae	Light trap	Defoliator		(Scott et al. 2010)
Herdonia thaiensis	Thyrididae	Light trap	Defoliator		
Pammene. Sp.	Tortricidae	D.S.M	Seed borer	Sal	DO, rearing and (Choubey et al. 2004)
Hemiptera					
Lohita grandis	Largidae	D.S.M and sweeping	Sap sucking	Botdhamero and foliage	DO
Physopelta schlanbuschi	Largidae	D.S.M	Sap sucking	Sal and foliage	DO and Basnet 1999
Physopelta gutta	Largidae	D.S.M	Sap sucking	BhuiKusum and foliage	DO
Physopelta sp.	Largidae	D.S.M and sweeping	Sap sucking	BhuiKusum and foliage	DO
Halyomorpha sp.	Pentatomidae	Sweeping	Sap sucking	unknown	(Bergmann et al. 2016)
Leptocorisa sp.	Alydidae	Sweeping	Sap sucking	unknown	(Mandanayake et al. 2014)
Ricania gutata	Ricaniidae	Light trap	Sap sucking	unknown	(Choi et al. 2017)
Vilius	Reduviidae	Sweeping	Sap	unknown	

melanopterus			sucking		
Recilia sp.	Cicadellidae	Beating	Sap sucking	unknown	(Sathe et al. 2014)
Orthoptera					
Acrida sp.	Acrididae	D.S.M and sweeping	Leaf eater	Sal	DO and (Roychoudhury 2015)
Hieroglyphus sp.	Acrididae	D.S.M and sweeping	Leaf eater	Teak and foliage	DO and (Roychoudhury et al. 2003)
Xenocatantops sp.	Acrididae	D.S.M and sweeping	Leaf eater	Sindure and foliage	DO
Phlaeoba sp.	Acrididae	D.S.M and sweeping	Leaf eater	Foliage	DO
Orthochtha sp.	Acrididae	D.S.M and sweeping	Leaf eater	Foliage	
Mecopoda sp.	Tettigonidae	D.S.M and sweeping	Leaf eater	Shrubs	DO
Letana sp.	Tettigonidae	D.S.M and sweeping	Leaf eater	Foliage	DO
Phaneroptera sp.	Tettigonidae	D.S.M and sweeping	Leaf eater	Shrubs	DO
Himmertula sp.	Tettigonidae	D.S.M and	Leaf eater	unknown	

		sweeping			
Hymenoptera					
Oecophylla sp.	Formicidae	Sweeping and beating	Leaf roller	Sal	DO and (Hazarika & Khanikor 2022)
Camponotus sp.	Formicidae	D.S.M.	Wood borer	Sal and Teak	DO and
Isoptera					
Coptotermes sp.	Rhinotermitidae	D.S.M.	Mud galleries	Teak	DO and (Patil et al. 2016, Costa et al. 2020)
Odontotermes obesus	Termitidae	D.S.M	Mud galleries	Sal and Teak	DO and (Rasib et al. 2014, Tripathy et al. 2020)

Appendix 2: Insect Pest Incidences During Pre-monsoon and Monsoon Periods in Natural Sal Forest and Planted Teak at KSFA, Morang District, 2021

Taxa	Family	Premonsoon	Monsoon
Coleoptera			
Epilachna dumerili	Coccinellidae	46	16
Hoplasoma unicolor	Chrysomelidae	23	21
Pseudocophara bicolor	Chrysomelidae	3	3
Heterapsis dillwyni	Chrysomelidae	5	0
Aulacophora sp.	Chrysomelidae	15	10
Chrysolina sp.	Chrysomelidae	12	0

Myllocerus sp.	Curculionidae	13	21
Tanymecus sp.	Curculionidae	6	6
Hypomeces squamosus	Curculionidae	0	6
Sitona sp.	Curculionidae	2	0
Naupactus sp.	Curculionidae	1	0
Hoplocerembyx spinicornis	Cerambycidae	1	10
Xylotrechus sp.	Cerambycidae	1	1
Apriona sp.	Cerambycidae	0	1
Philanthaxia sp.	Buprestidae	1	0
Agrypnus sp.	Elateridae	8	7
Adelocera sp.	Elateridae	7	3
Dicronychus sp.	Elateridae	13	4
Lepidoptera			
Lamida sp.	Pyralidae	1	0
Macalla sp.	Pyralidae	1	0
Arctonis sp.	Erebidae	2	1
Artena dotata	Erebidae	1	1
Thyas coronate	Erebidae	1	1
Parasa argentilinea	Erebidae	2	2
Scopelodes sp.	Erebidae	1	1
Achaea janata	Erebidae	1	2
Conogethes evaxalis	Crambidae	9	6
Conogethes punctiferalis	Crambidae	2	3
Herpetogramma phaeopteralis	Crambidae	15	26
Agrotera scissalis	Crambidae	21	30

Eoophyla peribocalis	Crambidae	5	4
Talanga sexpunctlis	Crambidae	3	4
Glyphodes bicolor	Crambidae	0	4
Palpita argentilinea	Crambidae	1	3
Paranacoleia lophophoralis	Crambidae	5	6
Ectropis bhurmitra	Geometridae	8	4
Biston suppressaria	Geometridae	3	3
Comostola laesaria	Geometridae	1	2
Thalassodes sp.	Geometridae	2	1
Geometrid unknown 1	Geometridae	3	3
Geometrid unknown 2	Geometridae	2	2
Episparis liturata	Noctuidae	3	2
Noctuid unknown 1	Noctuidae	2	1
Cyclidia substigmaria	Drepanidae	5	4
Herdonia thaiensis	Thyrididae	3	1
Pammene. sp.	Tortricidae	0	1
Hemiptera			
Lohita grandis	Largidae	0	14
Physopelta schlanbuschi	Largidae	0	6
Physopelta gutta	Largidae	0	8
Physopelta sp.	Largidae	10	24
Halyomorpha sp.	Pentatomidae	1	0
Leptocorisa sp.	Alydidae	0	12
Ricania gutata	Ricaniidae	19	11
Vilius melanopterus	Reduviidae	0	5

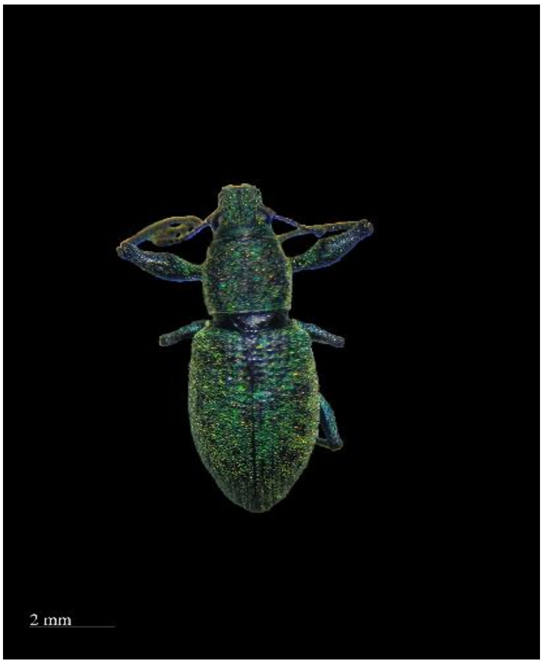
Recilia sp.	Cicadellidae	6	0
Orthoptera			
Acrida sp.	Acrididae	2	0
Hieroglyphus sp.	Acrididae	0	5
Xenocatantops sp.	Acrididae	3	0
Phlaeoba sp.	Acrididae	0	8
Orthochtha sp.	Acrididae	2	0
Mecopoda sp.	Tettigonidae	1	5
Letana sp.	Tettigonidae	0	1
Phaneroptera sp.	Tettigonidae	7	18
Himmertula sp.	Tettigonidae	0	2
Hymenoptera			
Oecophylla sp.	Formicidae	148	54
Camponotus sp.	Formicidae	56	43
Isoptera			
Coptotermes sp.	Rhinotermitidae	8	14
Odontotermes obesus	Termitidae	187	225
Total		710	682

PHOTOPLATES

Adelocera sp.

Tanymecus sp

Agrypnus sp.



Hypomecus squamosus

Myllocerus sp.

Philanthaxia sp.

Epilachna dumerili

8.*Hoplocerymbyx spinicornis*

Apriona sp.

Odontotermes sp.

Phaneroptera sp.

Phlaeoba sp.

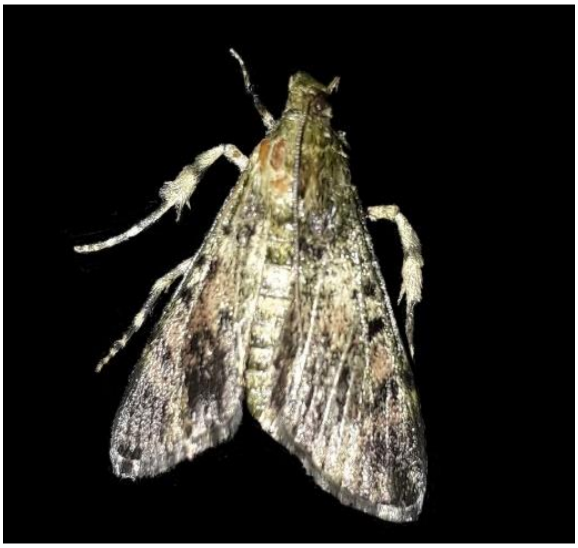
Macalla sp. larva

14. *Lamida* sp. larva

Pammene. sp. larva

Eoophyla peribocalis

Herpetogramma phaeopteralis



Lamida sp.

Comostola laesaria

Biston suppressaria

Artena dotata

Arctornis sp. larva feeding on Sal leaf