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# Survey on Rice Insects in Chitwan and Lamjung, Nepal

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## ABSTRACT

This study was conducted to assess the abundance and diversity of insect pests at different growth stages of rice crops. Under two different climatic factors, the data on rice insect pests in the various growth stages of rice crops revealed that the number of insect species in Chitwan was higher (22) than that in Lamjung (15). 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; however, the catch rate of *Leptocorisa acuta* (Thunberg) was the highest at the milking and hard dough stages. *Hieroglyphus banian* (Fabricius) was found from rice transplanting to harvesting, but was most abundant at the tillering stage in both areas. Moreover, *Scirpophaga incertulas* Walker was observed throughout the crop season, while its highest abundance were at the tillering stage in Chitwan and the milking stage in Lamjung. The highest number of *Cnaphalocrosis medinalis* Guenée occurred at the booting and heading stage in Chitwan only; however, *Dicladispa armigera* Oliver had the highest number at the tillering stage in Lamjung. In conclusion, the species richness (SR) and abundance (S) of rice insects reached their highest levels at the tillering, flowering, and milking stages of the rice crop, and then declined at the grain ripening stage. Furthermore, the species diversity (Hs) of rice insects fluctuate throughout the rice crop stages and reaches the highest numbers at the grain ripening stage in both areas.

**Key words:** Climatic parameters, abundance, rice growth stages, insects

## Introduction

Rice (*Oryza sativa* L) is the major staple food in Nepal. Rice occupies approximately 1,363 thousand hectares of land (56.42% of cultivated land) and 4,299.08 thousand tons of rice grains are produced with a national productivity of 3.15 tons/ha (Anonymous, 2016). In Nepal, rice is grown in three agroecological regions (Terai and Inner Terai, 67 to 900 amsl; Mid Hills, 1,000 to 1,500 amsl; and High Hills, 1,500 to 3,050 amsl) and in three major production environments, namely irrigated and rainfed lowlands and upland.

Several factors are responsible for reducing the production of rice. Among them, insect pests cause considerable losses in terms of quality and quantity (NARC, 1999). Over 800 insect pests have been reported to infest rice but only a few cause serious damage and require management. Insect pests cause a 25~30% loss in the production of rice in Nepal. Thapa and Tiwari (2010) reported that brown plant hoppers, leaf folders, grasshoppers, rice ear-head bugs, and yellow stem borers are the major rice pests in Nepal. Among these, the rice leaf folder (*Cnaphalocrosis medinalis* Guenée), once considered a minor pest, has now acquired the status of a major pest due to it causing widespread damage to rice crops worldwide (Teng *et al*., 1993). Rice leaf folders and caseworms (*Nymphula depunctalis* Guenée) attack the rice plant by feeding on the leaves, directly reducing photosynthesis and ultimately yield, which is dependent on plant age and rice variety. Almost all rice varieties are susceptible to attack by the rice ear-head bug (*Leptocorisa acuta* Thunberg), which attacks rice plants at the milking stage and causes considerable damage to the grain. The grasshopper (*Caelifera* spp.) is a devastating insect pest. It causes damage to rice leaves, resulting in yield reduction. The rice plant passes through vegetative (germination to panicle initiation), reproductive (panicle development-flowering), and ripening (milk grain to mature grain) stages. Each of these stages supports a particular species of insects. Consequently, rice fields have greater biodiversity compared with other tropical rainfed systems (Schoenly *et al*., 1998). Because no such study has been conducted in Nepal, we conducted this study to gather information to develop suitable tools for the integrated control of rice insect pests in local cropping systems. This study successfully gathered information about major insect pests and insect communities in rice-based cropping systems of two different agroecological systems in Nepal.

## Material and Methods

### Study sites

Rice insect pests were monitored at two sites: Rampur, Chitwan and Sundar bazzar, Lamjung from July to November 2015. All the study areas were farmland with different soil types and cropping patterns. In Nepal, rice is cultivated at extreme altitudes ranging from tropical plains (60 masl, Kechanakal, Jhapa) to temperate mountains (3,050 masl, Chhumchour, Jumla) (Paudel, 2011), which have the highest elevation in the world. To assess the numbers of pest insects from a fixed plot, rice was grown in its main season in Chitwan (228 masl) to represent a tropical plain with a cool winter and hot summer, and in Lamjung (1,420 masl) to represent mid-level hills with a cool and warm climate. Details of the study sites are listed in Tables 1 and 2.

### Experimental design

The Ramdhan variety of rice was transplanted on July 29, 2015 and typical agronomic practices were followed as recommended by the NARC (2006). No pesticides were sprayed during the study. Ramdhan is a medium tillering, medium panicle-initiation duration, medium height, drought tolerant, soft grain, and an insect-pest-susceptible variety of rice (Khanal and Badal, 2015).

A fixed plot of one unit (333.33 $m^2$) each was selected at both areas where five random spots of 1 $ft^2$ (four in the corners at 1.5 m inside from the border and one in the center) were selected as five replications for observation of the insects. The observations were performed at 7-day intervals starting from 21 days after planting until the harvest. We considered locations and crop stages as factors; therefore, two-factorial RCBD was used. The data were subjected to square root transformation and the complete recorded data were analyzed using R Studio.

Details of the sampling methods for the pest insects are listed in Table 3. Similarly, for natural enemies, an absolute sampling method was used to observe the number of insects (field count) on plant canopies, with the whole plant considered as a sampling unit. This is the most commonly used sampling method for aboveground populations of insects (Kogan and Pitre, 1980). The insect population data were

Table 1. Characteristics of the study sites

| Study areas | Geographical coordination | Cropping pattern | Soil type |
|---|---|---|---|
| Chitwan, Rampur (Plain) | 27°40'N84°19'E, 228 masl | Rice-Wheat-Maize (Irrigated)<br>Rice-Wheat-Fallow (Rainfed) | Sandy |
| Lamjung, Sundar bazzar (Mid hill) | 28°12'N84°22'E, 1420 masl | Rice-Wheat-Maize (Irrigated)<br>Maize + Upland rice-Wheat (Rainfed) | Sandy loam |

Table 2. Temperature, RH, and rainfall during the rice growing period in Chitwan and Lamjung, Nepal

| Months | Temperature (°C) | | RH (%) | | Rainfall (mm) | |
|---|---|---|---|---|---|---|
| | Chitwan | Lamjung | Chitwan | Lamjung | Chitwan | Lamjung |
| June | 35.42 | 31.35 | 76.80 | 79.97 | 306.80 | 475.27 |
| July | 34.27 | 30.84 | 84.65 | 87.04 | 417.50 | 757.53 |
| August | 33.19 | 30.90 | 84.77 | 86.64 | 461.20 | 699.63 |
| September | 32.57 | 31.27 | 89.20 | 83.80 | 00.00 | 331.10 |
| October | 31.83 | 28.41 | 84.32 | 80.75 | 04.20 | 120.95 |
| November | 28.20 | 25.69 | 89.20 | 73.02 | 00.00 | 00.00 |
| Average | 32.58 | 29.72 | 84.82 | 81.87 | 198.28 | 397.41 |

Table 3. Sampling technique used for rice insect pests (adopted from NICRA, 2011)

| Insect | Sampling technique |
|---|---|
| Stem borer | Counting the dead hearts (dried tillers) at the tillering stage and white ear heads after panicle emergence in each hill. In addition, counting the total number of larvae and adults in each hill. |
| Leaf folder | Counting the number of folded leaves per hill when more than 30% of a leaf is damaged. In addition, counting the total number of larvae and adults in each leaf per hill. |
| Caseworm | Counting the total adults and damaged leaves due to case worms per hill and recording them. |
| Brown plant hopper (BPH) | Recording the total number of hoppers (nymphs and adults) on all tillers of each hill. For tiller damage, counting the number of damaged tillers per hill. |
| Leaf hopper | Counting the number of nymphs and adults of all hoppers other than BPH in each hill. |
| Rice horned caterpillar and army worm | Counting the total number of caterpillars, adults, and damaged leaves in each hill, and then recording them separately. |
| Rice ear-head bug | Counting and recording the number of nymphs and adults together on each hill. |
| Blue beetle | Counting and recording the number of immature stages and adults together on each hill. |
| Black bugs and grasshoppers | Counting and recording the number of nymphs and adults together on each hill. |
| Rice skipper, pollen beetle, and rice hispa | Counting and recording the number of adults together on each hill. |

Table 4. Insect orders associated with rice agroecosystems in Chitwan and Lamjung, Nepal

| Order | Total insects (%) | |
|---|---|---|
| | Chitwan | Lamjung |
| Coleoptera | 12 | 37 |
| Diptera | 2 | 4 |
| Hemiptera | 15 | 6 |
| Hymenoptera | 6 | 15 |
| Lepidoptera | 37 | 9 |
| Odonata | 12 | 19 |
| Orthoptera | 16 | 10 |
| Total | 100 | 100 |

sowing until harvest from five random spots of one square foot. Four spots were at the corners of the field at least 1.5 m inside from the border and one was at the center.

The collected samples were brought to the Laboratory of Entomology, Nepal Agriculture Research Council, Lalitpur, Nepal for identification and preservation. At least 10 insect specimens of each species were preserved for future reference.

**Diversity indices**

Species richness (SR, number of species), abundance (S, number of individuals), and diversity were analyzed during this study. The diversity indices assume that individuals were randomly sampled from an infinitely large population. The Shannon-Weaver index (Hs) was used to describe the biodiversity within the total insect community in the rice field. The function for the index is as follows:

$$Hs = -\sum_{i=1}^{s} Pi \ln Pi$$

Where Hs is the index for insect diversity in a group of s species and Pi is the relative abundance of species i.

SR was determined by counting the numbers of insect species and S was determined by counting the number of individuals of each species.

## Results

**Insects associated with rice agroecosystems**

Rice fields are temporary wetland agroecosystems managed with a variable degree of intensity (Bambaradeniya *et al.*, 2004). The abundance of total numbers of insects and insect orders was higher in Chitwan than in Lamjung. In Chitwan, the abundance of Lepidopteran insects (37%) was highest, followed by Orthopteran (16%), Coleopteran (12%), and Odonata (12%) insects. However, in Lamjung, most insects were associated with the order Coleoptera (37%), followed by Odonata (19%) and Hymenoptera (15%). No Hemipteran insects were observed in Lamjung and Dipteran insects were observed the least in Chitwan (Table 4).

Regarding SR in both locations, Lamjung and Chitwan had 111 and 465 species of insects, respectively; that is, Chitwan's SR was more than four folds higher than that of Lamjung. Chitwan had an almost two-fold higher number of beneficial insects than Lamjung. Similarly, Chitwan also had 8.8 folds more pest insects than Lamjung (Table 5).

The Hs values of Lamjung and Chitwan were 2.38 and 2.92, respectively; that is, Chitwan's Hs value was 1.1-fold higher than that of Lamjung. When the total species were categorized as beneficial or pest insects and compared between locations, the Hs value of beneficial insects in Lamjung was almost 1.6-fold higher than that of Chitwan. Similarly, the Hs value of Chitwan's pest insects was 1.8-fold higher than that of Lamjung (Table 5).

In Chitwan, among the pest insects, grasshoppers (69) were observed in the highest numbers followed by leaf folders (60) and green horn caterpillars (36). Other species observed during the study were case worms (30), white leafhoppers (28), yellow stem borers (27), blue beetles (11), green leafhoppers (14), and pollen beetles (2). No armyworms or rice hispa were observed during this study (Table 5).

The Hs value for pest insects in Chitwan followed the same trend as species abundance trends. Grasshoppers had the highest Hs value (0.27) followed by leaf folders (0.25) and green horn caterpillars (0.19; Table 5).

In Chitwan, among the beneficial insects, ladybird beetles were observed in the highest numbers (30) followed by damselflies (26) and dragonflies (25). Other species observed during the study were ichneumonid wasps (18), rove beetles (11), antlions (4), assassin bugs (3), braconid wasps (6), ground beetles (5), robber flies (10), and tiger beetles (3) (Table 5).

Table 5. Diversity of rice insects in Chitwan and Lamjung, Nepal

| Species | Scientific name | Order: Family | Chitwan | | Lamjung | |
|---|---|---|---|---|---|---|
| | | | S | Hs | S | Hs |
| **Pest insects** | | | | | | |
| Armyworm | *Spodoptera frugiperda* Smith | Lepidoptera: Noctuidae | 0 | 0.00 | 2 | 0.07 |
| Blue beetle | *Chrysochus cobaltinus* LeConte | Coleoptera: Chrysomelidae | 11 | 0.08 | 9 | 0.19 |
| Caseworm | *Nymphula depunctalis* Guenée | Lepidoptera: Pyralidae | 30 | 0.17 | 1 | 0.04 |
| Grasshopper | *Caelifera* spp.Fab. | Orthoptera: Tridactyloidea | 69 | 0.27 | 9 | 0.19 |
| Green horn caterpillar | *Melanitis leda ismene* Cramer | Lepidoptera: Satyridae | 36 | 0.19 | 4 | 0.11 |
| Green leaf hopper | *Nephotettix nigropictus* Stal | Hemiptera: Cicadellidae | 14 | 0.10 | 0 | 0.00 |
| Leaf folder | *Cnaphalocrocis medinalis* Guenée | Lepidoptera: Pyralidae | 60 | 0.25 | 0 | 0.00 |
| Pollen beetle | *Meligethes aeneus/viridescens* Fab. | Coleoptera: Kateretidae | 2 | 0.02 | 0 | 0.00 |
| Rice ear head bug | *Leptocorisa acuta* Fab. | Hemiptera: Alydidae | 20 | 0.13 | 6 | 0.14 |
| Rice hispa | *Dicladispa armigera* Oliver | Coleoptera: Chrysomelidae | 0 | 0.00 | 5 | 0.13 |
| Skipper | *Hesperia comma* L. | Lepidoptera: Hesperiidae | 27 | 0.15 | 0 | 0.00 |
| White leaf hopper | *Eratoneura stephensoni* Stal | Hemiptera: Cicadellidae | 28 | 0.16 | 0 | 0.00 |
| Yellow stem borer | *Scirpophaga incertulas* Walker | Lepidoptera: Pyralidae | 27 | 0.15 | 1 | 0.04 |
| ***Species richness (SR)*** | | | ***11*** | | ***8*** | |
| ***Total (Pest insects)*** | | | ***324*** | ***1.67*** | ***37*** | ***0.91*** |
| **Beneficial insects** | | | | | | |
| Antlion | *Glenurus* spp. | Neuroptera: Myrmeleontidae | 4 | 0.04 | 0 | 0.00 |
| Assasian bug | *Pselliopus* spp. | Hemiptera: Reduviidae | 3 | 0.03 | 0 | 0.00 |
| Braconid wasp | *Atanycolus* spp. | Hymenoptera: Braconidae | 6 | 0.05 | 5 | 0.13 |
| Damselfly | *Ischnura senegalensis* Rambur | Odonata: Coenagrionidae | 26 | 0.15 | 4 | 0.11 |
| Dragonfly | *Orthetrum cancellatum* L. | Odonata: Libellulidae | 25 | 0.15 | 14 | 0.24 |
| Ground beetle | *Aephnidius ruficornis* Chaudoir | Coleoptera: Carabidae | 5 | 0.05 | 3 | 0.09 |
| Ichneumonid wasp | *Rhyssa persuasoria* L. | Hymenoptera: Ichneumonidae | 18 | 0.12 | 8 | 0.17 |
| Lady bird beetle | *Hippodamia convergens* Guérin-Méneville | Coleoptera: Coccinellidae | 30 | 0.17 | 19 | 0.28 |
| Robber fly | *Laphria* spp. | Diptera: Asilidae | 10 | 0.08 | 4 | 0.11 |

Table 5. continued

| Species | Scientific name | Order: Family | Chitwan | | Lamjung | |
|---|---|---|---|---|---|---|
| | | | S | Hs | S | Hs |
| Rove beetle | *Aleochara bipustulata* L. | Coleoptera: Staphylinidae | 11 | 0.08 | 13 | 0.23 |
| Tiger beetle | *Cicindela tranquebarica* Herbst | Coleoptera: Carabidae | 3 | 0.03 | 4 | 0.11 |
| ***Species richness (SR)*** | | | ***11*** | | ***9*** | |
| ***Total (Beneficial insects)*** | | | ***141*** | ***0.95*** | ***74*** | ***1.47*** |
| ***Total (pest insects and beneficial insects)*** | | | ***465*** | ***2.62*** | ***111*** | ***2.38*** |
| ***Total Species richness (SR)*** | | | ***22*** | | ***15*** | |

S = Number of individuals (abundance), Hs = Shannon-Weaver diversity index

The Hs value for beneficial insects in Chitwan also followed the same trend as species abundance. Ladybird beetles had the highest Hs value (0.17) followed by damselflies (0.15) and dragonflies (0.15) (Table 5).

In Lamjung, among the pest insects, blue beetles were observed in the highest numbers (9), followed by grasshoppers (9), rice ear-head bugs (6) and rice hispa (5). Other species observed during the study were armyworms (2), caseworms (1), green horn caterpillars (4), and yellow stem borers (1). No green leafhoppers, leaf folders, pollen beetles, skippers, or white leafhoppers were observed during the study (Table 5).

The Hs value for pest insects in Lamjung also followed the same trend as species abundance. Blue beetles had the highest Hs value (0.19), followed by grasshoppers (0.19) and rice ear-head bugs (0.14) (Table 5).

In Lamjung, among the beneficial insects, ladybird beetles were observed in the highest numbers (19), followed by dragonflies (14), rove beetles (13), and ichneumonid wasps. Other species observed during the study were wasps (5), damselflies (4), ground beetles (3), robber flies (4), and tiger beetles (4). Antlions and assassin bugs were absent during the study (Table 5).

The Hs value for beneficial insects in Lamjung also followed the same trend as species abundance. Ladybird beetles had the highest Hs value (0.28) followed by dragonflies (0.24) and rove beetles (0.23) (Table 5).

**Biodiversity of insects at different growth stages of rice**

The results demonstrated that SR, number of insect species, and insect diversity were higher in Chitwan than Lamjung for all growth stages of rice (Table 6).

The number of insect pests was highest during the booting and tillering stages in Chitwan and Lamjung, respectively (Figure 1 and 2).

In Chitwan, the total number of pest species was highest in the booting stage and lowest in the tillering stage. However, pest SR and Hs values were highest in the milking stage. Similarly, in Lamjung, the total number of pest species was highest and lowest in the tillering and panicle initiation stages, respectively. However, pest SR and Hs values were highest in the tillering stage (Table 6).

In Chitwan, the total number of beneficial insect species was highest and lowest in the anthesis and tillering stages, respectively. Moreover, beneficial SR and Hs values were highest in the anthesis stage as well. Similarly, in Lamjung, the total number of beneficial insect species was highest and lowest in the panicle initiation and tillering stages, respectively. Similarly, beneficial insect SR and Hs values were highest in the panicle initiation stage (Table 6).

The numbers of insects observed during the study were correlated with climatic parameters. Rice grown in the monsoon season was attacked by numerous pests in the vegetative stage. The total number of pest insects in the rice crop were directly correlated with the mean temperature

Table 6. Diversity of rice insects at different growth stages of rice in Chitwan and Lamjung, Nepal

| Growth stage of rice | Chitwan | | | Lamjung | | |
|---|---|---|---|---|---|---|
| | S | SR | Hs | S | SR | Hs |
| **Pest Insects** | | | | | | |
| Tillering | 39 | 9 | 1.55 | 13 | 5 | 1.19 |
| Panicle initiation | 47 | 9 | 1.55 | 1 | 1 | 0.18 |
| Booting/ heading | 56 | 9 | 1.56 | 3 | 2 | 0.42 |
| Anthesis | 54 | 10 | 1.52 | 3 | 3 | 0.48 |
| Milking | 45 | 11 | 1.76 | 6 | 5 | 0.81 |
| Soft dough | 43 | 10 | 1.63 | 3 | 3 | 0.34 |
| Hard dough | 40 | 10 | 1.60 | 8 | 4 | 0.87 |
| ***Total*** | ***324*** | ***11*** | ***11.17*** | ***37*** | ***8*** | ***4.29*** |
| **Beneficial insects** | | | | | | |
| Tillering | 14 | 7 | 0.95 | 7 | 3 | 0.76 |
| Panicle initiation | 17 | 7 | 0.90 | 14 | 8 | 1.91 |
| Booting / heading | 19 | 8 | 0.88 | 14 | 7 | 1.48 |
| Anthesis | 26 | 11 | 1.12 | 14 | 6 | 1.54 |
| Milking | 18 | 9 | 1.04 | 15 | 7 | 1.62 |
| Soft dough | 23 | 8 | 1.01 | 12 | 5 | 1.29 |
| Hard dough | 24 | 9 | 1.17 | 13 | 5 | 1.18 |
| ***Total*** | ***141*** | ***11*** | ***7.07*** | ***89*** | ***9*** | ***9.78*** |

S = Number of individuals (abundance), SR = species richness, Hs = Shannon-Weaver diversity index.

and indirectly correlated with rainfall amount (Table 7).

In Chitwan, the weather was slightly warmer (approximately 30°C) during the tillering stage and temperature decreased to approximately 25°C at the hard dough stage. Heavy rain was noted during the initial growth stage followed by no rain or limited rain (Table 2). The number of pest insects increased with the crop stage and time, reaching their highest level at the booting and milking stages, and then the number decreased with time. At the hard dough stage, the number of insect pests decreased to the minimum number (Figure 1).

Similarly, the number of beneficial insects increased with time and crop stages and reached its highest level at the anthesis stage. During the milking stage, the number of beneficial insects decreased with declining temperature but increased again after the milking stage to the soft dough stage and then remained stable until the hard dough stage (Figure 1).

The number of insects increased with time and crop stage, reaching its highest level at the anthesis stage of rice and then started to decline, while remaining higher than the initial numbers until the hard dough stage (Figure 1).

Regarding the number of top five insect pests observed during the study, the grasshopper had the highest number at the beginning of the study followed by caseworms, green horn caterpillars, and white leafhoppers. The leaf folders reached their highest level at the booting stage and started to decline with the rice growth stages. The number of grasshoppers remained stable until the panicle initiation stage and then started to decline with growth stages. Similarly, caseworms, green horn caterpillars, and white leafhoppers increased with time and reached their highest level at the booting, anthesis, and soft dough stages of rice, respectively (Table 8).

Regarding the number of top five beneficial insects observed during the study, damselflies, dragonflies, and rove beetles had the highest numbers in the beginning of the study, followed by ladybird beetles and ichneumonid wasps. All reached their highest levels at the anthesis stage and then declined slightly at the milking stage, reaching their second highest levels at the soft dough stage. At the hard dough stage, ladybird beetles had the highest number, followed by damselflies, ichneumonid wasps, and dragonflies

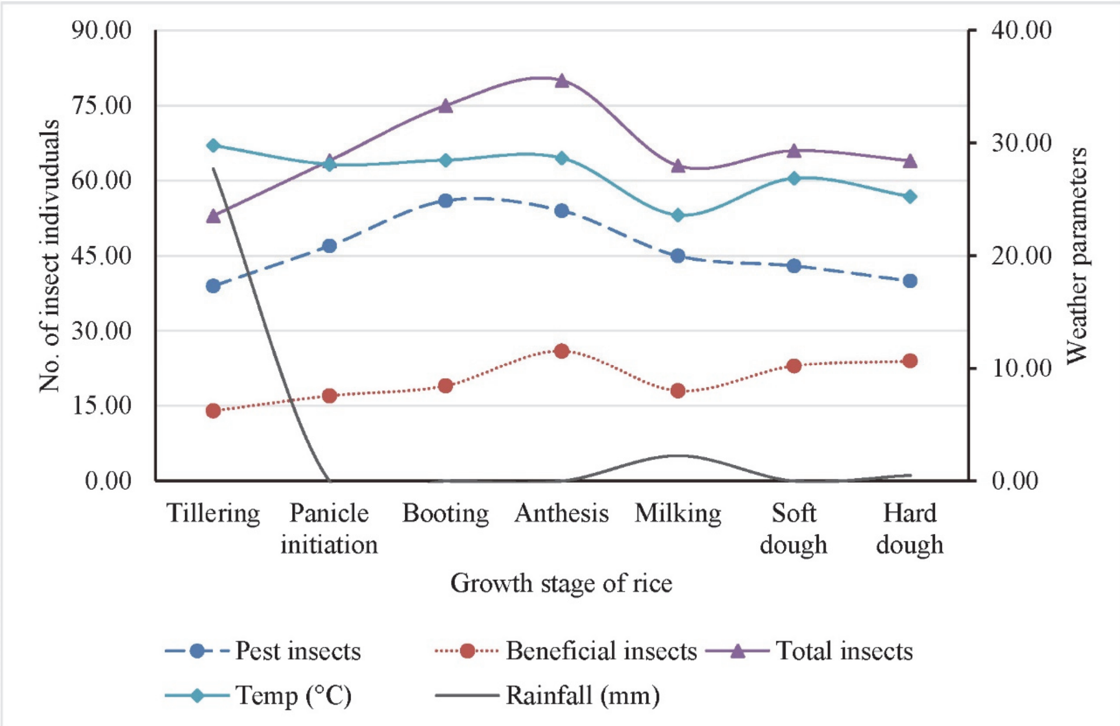


Fig. 1. Relationship between climatic parameters and total insect occurrence at different growth stages of rice in Chitwan, Nepal.

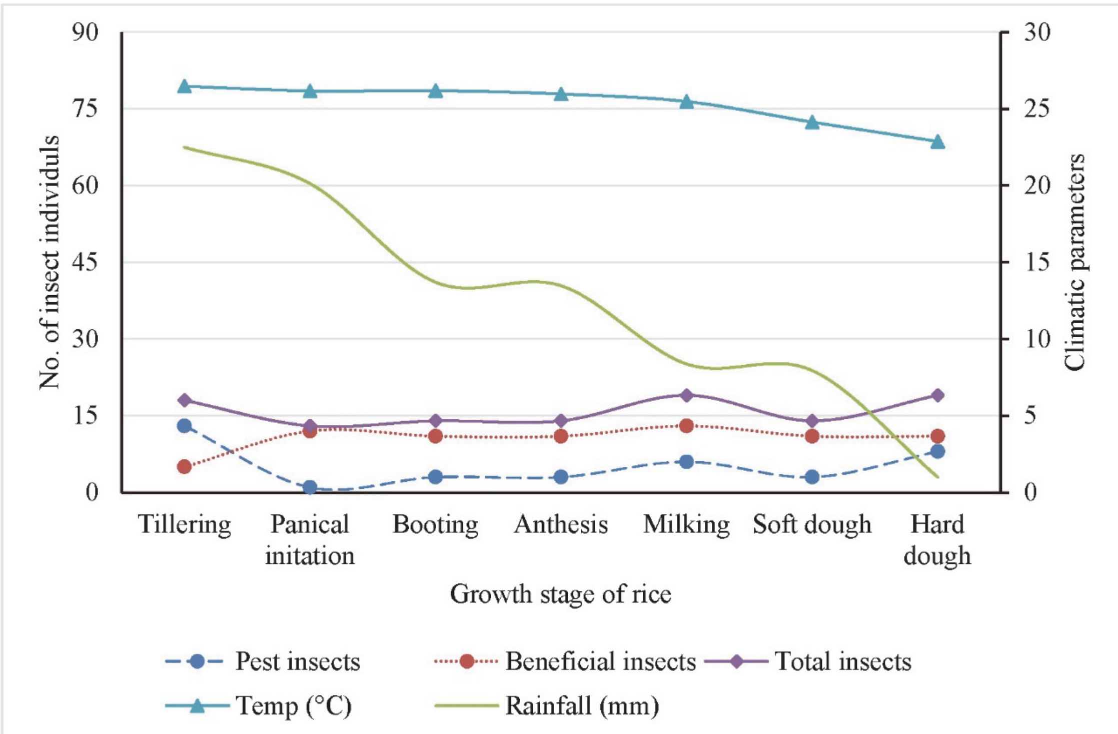


Fig. 2. Relationship between climatic parameters and total insect occurrence at different growth stages of rice in Lamjung, Nepal.

Table 7. Correlation between insect pests of rice and climatic parameters

| Climatic Parameters | Rice insect pests |
|---|---|
| Mean Temperature | 0.56* |
| Rainfall | -0.44* |

*Significant at the 0.05 level.

(Table 8).

In Lamjung, the weather was not warm (approximately 27°C) during the tillering stage and the temperature decreased to approximately 23°C at the hard dough stage. Rainfall was present between the beginning and end of the study; however, rain intensity decreased with time. The number of pest insects was highest at the tillering stage and then decreased to its minimum level during the panicle initiation stage. The number of pest insects started to increase after the panicle stage and reached its highest level at hard dough stage (Figure 2).

The number of beneficial insects increased

Table 8. Diversity of different insect species at different growth stages of rice in Chitwan, Nepal

| Insects | Tillering | | Panicle initiation | | Booting | | Anthesis | | Milking | | Soft dough | | Hard dough | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | S | Hs | S | Hs | S | Hs | S | Hs | S | Hs | S | Hs | S | Hs |
| **Pest insects** | | | | | | | | | | | | | | |
| Blue beetle | 1 | 0.07 | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 | 2 | 0.10 | 4 | 0.16 | 4 | 0.16 |
| Caseworm | 5 | 0.21 | 6 | 0.21 | 7 | 0.21 | 4 | 0.14 | 3 | 0.14 | 2 | 0.10 | 3 | 0.14 |
| Grasshopper | 12 | 0.32 | 12 | 0.30 | 11 | 0.27 | 9 | 0.23 | 9 | 0.27 | 8 | 0.24 | 8 | 0.25 |
| Green horn caterpillar | 3 | 0.15 | 5 | 0.18 | 5 | 0.17 | 8 | 0.21 | 6 | 0.21 | 5 | 0.18 | 4 | 0.16 |
| Green leaf hopper | 1 | 0.07 | 2 | 0.10 | 1 | 0.05 | 1 | 0.05 | 3 | 0.14 | 3 | 0.13 | 3 | 0.14 |
| Leaf folder | 5 | 0.21 | 10 | 0.27 | 18 | 0.33 | 15 | 0.30 | 6 | 0.21 | 2 | 0.10 | 4 | 0.16 |
| Pollen beetle | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 | 1 | 0.05 | 1 | 0.06 | 0 | 0.00 | 0 | 0.00 |
| Rice ear-head bug | 0 | 0.00 | 1 | 0.06 | 2 | 0.09 | 5 | 0.16 | 4 | 0.17 | 4 | 0.16 | 4 | 0.16 |
| Rice hispa | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 |
| Skipper | 6 | 0.23 | 6 | 0.21 | 4 | 0.15 | 4 | 0.14 | 2 | 0.10 | 3 | 0.13 | 2 | 0.10 |
| White leaf hopper | 2 | 0.11 | 2 | 0.10 | 3 | 0.12 | 4 | 0.14 | 6 | 0.21 | 7 | 0.23 | 4 | 0.16 |
| Yellow stem borer | 4 | 0.18 | 3 | 0.13 | 5 | 0.17 | 3 | 0.11 | 3 | 0.14 | 5 | 0.18 | 4 | 0.16 |
| ***Species richness (SR)*** | ***9*** | | ***9*** | | ***9*** | | ***10*** | | ***11*** | | ***10*** | | ***10*** | |
| ***Total*** | ***39*** | ***1.55*** | ***47*** | ***1.57*** | ***56*** | ***1.56*** | ***54*** | ***1.53*** | ***45*** | ***1.75*** | ***43*** | ***1.61*** | ***40*** | ***1.59*** |
| **Beneficial insects** | | | | | | | | | | | | | | |
| Antlion | 0 | 0.00 | 1 | 0.06 | 0 | 0.00 | 1 | 0.05 | 1 | 0.06 | 1 | 0.06 | 0 | 0.00 |
| Assasian bug | 1 | 0.07 | 0 | 0.00 | 1 | 0.05 | 1 | 0.05 | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 |
| Braconid wasp | 0 | 0.00 | 1 | 0.06 | 1 | 0.05 | 1 | 0.05 | 1 | 0.06 | 1 | 0.06 | 1 | 0.06 |
| Damselfly | 4 | 0.18 | 5 | 0.18 | 4 | 0.15 | 5 | 0.16 | 2 | 0.10 | 2 | 0.10 | 4 | 0.16 |
| Dragonfly | 4 | 0.18 | 4 | 0.16 | 4 | 0.15 | 5 | 0.16 | 2 | 0.10 | 3 | 0.13 | 3 | 0.14 |
| Ground beetle | 1 | 0.07 | 1 | 0.06 | 0 | 0.00 | 1 | 0.05 | 1 | 0.06 | 0 | 0.00 | 1 | 0.06 |
| Ichneumonid wasp | 1 | 0.07 | 2 | 0.10 | 2 | 0.09 | 3 | 0.11 | 3 | 0.14 | 4 | 0.16 | 3 | 0.14 |
| Lady bird beetle | 2 | 0.11 | 3 | 0.13 | 3 | 0.12 | 5 | 0.16 | 4 | 0.17 | 7 | 0.23 | 6 | 0.21 |
| Robber fly | 0 | 0.00 | 0 | 0.00 | 2 | 0.09 | 1 | 0.05 | 2 | 0.10 | 3 | 0.13 | 2 | 0.10 |
| Rove beetle | 0 | 0.00 | 0 | 0.00 | 2 | 0.09 | 2 | 0.08 | 2 | 0.10 | 2 | 0.10 | 3 | 0.14 |
| Tiger beetle | 1 | 0.07 | 0 | 0.00 | 0 | 0.00 | 1 | 0.05 | 0 | 0.00 | 0 | 0.00 | 1 | 0.06 |
| ***Species richness (SR)*** | ***7*** | | ***7*** | | ***8*** | | ***11*** | | ***9*** | | ***8*** | | ***9*** | |
| ***Total*** | ***14*** | ***0.75*** | ***17*** | ***0.75*** | ***19*** | ***0.79*** | ***26*** | ***0.97*** | ***18*** | ***0.89*** | ***23*** | ***0.97*** | ***24*** | ***1.07*** |

S = Number of individuals (abundance), Hs = Shannon-Weaver diversity index.

Table 9. Biodiversity of different insect species at different growth stages of rice in Lamjung, Nepal

| Insects | Tillering | | Panicle initiation | | Booting | | Anthesis | | Milking | | Soft dough | | Hard dough | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | S | Hs | S | Hs | S | Hs | S | Hs | S | Hs | S | Hs | S | Hs |
| **Pest insects** | | | | | | | | | | | | | | |
| Armyworm | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0.18 | 1 | 0.15 |
| Blue beetle | 3 | 0.28 | 1 | 0.18 | 0 | 0 | 1 | 0.16 | 1 | 0.2 | 1 | 0.18 | 2 | 0.22 |
| Caseworm | 1 | 0.15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Grasshopper | 3 | 0.28 | 0 | 0 | 1 | 0.17 | 1 | 0.16 | 1 | 0.2 | 1 | 0.18 | 2 | 0.22 |
| Green horn caterpillar | 1 | 0.15 | 0 | 0 | 2 | 0.25 | 0 | 0 | 1 | 0.2 | 0 | 0 | 0 | 0 |
| Rice ear-head bug | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0.16 | 2 | 0.2 | 0 | 0 | 3 | 0.28 |
| Rice hispa | 5 | 0.34 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Yellow stem borer | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0.2 | 0 | 0 | 0 | 0 |
| ***Species richness (SR)*** | ***5*** | | ***1*** | | ***2*** | | ***3*** | | ***5*** | | ***3*** | | ***4*** | |
| ***Total*** | ***13*** | ***1.2*** | ***1*** | ***0.18*** | ***3*** | ***0.42*** | ***3*** | ***0.48*** | ***6*** | ***1*** | ***3*** | ***0.54*** | ***8*** | ***0.87*** |
| **Beneficial insects** | | | | | | | | | | | | | | |
| Braconid wasp | 0 | 0 | 1 | 0.18 | 1 | 0.17 | 2 | 0.24 | 0 | 0 | 1 | 0.18 | 0 | 0 |
| Damselfly | 1 | 0.15 | 2 | 0.27 | 0 | 0 | 1 | 0.16 | 0 | 0 | 0 | 0 | 0 | 0 |
| Dragonfly | 2 | 0.22 | 3 | 0.32 | 2 | 0.25 | 2 | 0.24 | 1 | 0.2 | 2 | 0.27 | 2 | 0.22 |
| Ground beetle | 0 | 0 | 0 | 0 | 2 | 0.25 | 0 | 0 | 1 | 0.2 | 0 | 0 | 0 | 0 |
| Ichneumonid wasp | 0 | 0 | 1 | 0.18 | 0 | 0 | 2 | 0.24 | 1 | 0.2 | 1 | 0.18 | 3 | 0.28 |
| Lady bird beetle | 2 | 0.22 | 2 | 0.27 | 3 | 0.31 | 2 | 0.24 | 4 | 0.3 | 3 | 0.32 | 3 | 0.28 |
| Robber fly | 0 | 0 | 1 | 0.18 | 1 | 0.17 | 0 | 0 | 2 | 0.2 | 0 | 0 | 0 | 0 |
| Rove beetle | 0 | 0 | 1 | 0.18 | 1 | 0.17 | 2 | 0.24 | 3 | 0.3 | 4 | 0.35 | 2 | 0.22 |
| Tiger beetle | 0 | 0 | 1 | 0.18 | 1 | 0.17 | 0 | 0 | 1 | 0.2 | 0 | 0 | 1 | 0.15 |
| ***Species richness (SR)*** | ***3*** | | ***8*** | | ***7*** | | ***6*** | | ***7*** | | ***5*** | | ***5*** | |
| ***Total*** | ***5*** | ***0.59*** | ***12*** | ***1.76*** | ***11*** | ***1.49*** | ***11*** | ***1.36*** | ***13*** | ***1.6*** | ***11*** | ***1.3*** | ***11*** | ***1.15*** |

S = Number of individuals (abundance), Hs = Shannon-Weaver diversity index.

with time and crop stages and reached its highest level at the panicle initiation stage. After the panicle initiation stage, the number of beneficial insects remained stable until the hard dough stage (Figure 2).

The total number of insects was more stable in Lamjung than in Chitwan. The total number of insects was highest from the tillering to milking stages and then started to decline to its minimum at the hard dough stage (Figure 2).

Regarding the top five insect pests observed during the study, rice hispas had the highest number at the beginning of the study, followed by blue beetles, grass hoppers, green horn caterpillars, and rice ear-head bugs. After the panicle initiation and booting stages, the number of rice hispas and blue beetles became low or absent. The number of rice ear-head bugs increased after the booting stage until the milking stage and then dropped to zero, reaching its highest level at the hard dough stage. Similarly, the number of grasshoppers remained the same from the booting stage until the soft dough stage and reached its highest level at the hard dough stage (Table 9).

Regarding the top five beneficial insects observed during the study, dragonflies had the highest number in the beginning of the study and the rest were absent. Ladybird beetles, rove beetles, ichneumonid wasps, and dragonflies were the most active natural enemies in the field (Table 8).

## Discussions

SR is the simplest and most frequently used diversity indicator. However, SR assessments are sensitive to scale, due to species-area relationship and sampling effort because of the difficulty of obtaining complete species lists (Palmer and White, 1994; Palmer, 1995). Our results indicated that SR and number of insects were higher in lower altitude areas (Chitwan) compared with higher altitude areas (Lamjung) in all the rice growth stages. However, SR fluctuated in both areas. Altieri (1999) reported that the abundance and diversity in agriculture differs across agroecosystems that differ in age, diversity, structure, and management. Destructive biota depends upon the diversity of vegetation and prominence of various crops within and around the agroecosystem, intensity of management, as well as the extent of the agroecosystem's isolation from natural vegetation. Chitwan and Lamjung had different cropping systems. Insect species exhibited higher densities in polyculture than monoculture (Andow, 1991; Jones and Lawton, 1991). That may have been due to the continual availability of food sources, microhabitats, and suitable host plants. Altieri (1993) also reported that structural (*i.e.*, spatial and temporal crop arrangement) and management (*i.e.*, crop diversity and input levels) attributes of agroecosystems influence herbivore dynamics and the abundance of natural enemies increases in response to their prey.

In our study, the diversity of pest insects was highest at the milking and tillering stages of the rice crops in Chitwan and Lamjung, respectively. Similar results were also reported by Asghar (2010). Asghar stated that the SR and abundance of herbivore insects increased with rice crop age and reached their maximum values at the flowering-milking stage of the crop and then declined at the grain ripening stage. In our study, the Hs value increased with crop age and was at its maximum at the grain ripening stage in both locations.

The diversity of beneficial insects in Chitwan was higher at the hard dough stage of rice. Asghar (2010) reported that the SR and abundance of non-rice pests (NRP) also increased with crop age and reached their maximum numbers at the flowering-milking and tillering stages. During our study, the Hs fluctuated throughout the crop stages and reached a maximum at the grain ripening stage. Asghar (2010) further reported that most of NRP species do not prefer rice at the tillering-booting stage compared with the other stages of rice.

The abundance of rice insects was higher in Chitwan than in Lamjung. High rainfall and low temperature might be responsible for the lower number of insects in Lamjung. Dixon *et al*. (2009) supported this fact. They reported that temperature acts as a limiting factor for the distribution and abundance of most rice insect pests.

The results indicated that the total number of insects was highest during the booting and heading stages of rice. Inthavong *et al.* (1998) reported that in general, the level of infestation increased as the rice plant aged.

Temperature had a direct effect on the growth and development of the insects. The results indicated that the total number of insects was higher in Chitwan than Lamjung. This study demonstrated that the abundance of caseworms increased with an increase in temperature. The number of leaf folders was not revealed in Lamjung during the study. Kiritani (1988) reported that rice leaf folders are rarely found in cooler regions.

The number of leaf folders increased with increasing temperature within a certain limit at the early growth stage of rice and then decreased toward crop maturity. The number of grasshoppers was highest at higher temperatures. The number of rice stem borers increased with increasing temperature. Kisimoto and Dyck (1976) reported that high temperature and low rainfall could cause a severe stem borer infestation. Ragini *et al.* (2000) reported a joint influence of rainfall, relative humidity, and mean minimum temperature on stem borer infestation.

The abundance of rice hispa was highest in Lamjung but they were absent in Chitwan. Kisimoto and Dyck (1976) reported that rainy and cloudy weather during the early crop period encouraged the survival and growth of rice hispa.

The results of this study revealed that caseworm infestation was more pronounced in the early growth stage of rice crops. Singh and Singh (2014) reported that rice at the seedling and tillering stages was the preferred host of caseworms. The incidence of leaf folders was highest at the booting and heading stages of rice in Chitwan. Cheng and Wu (1999) reported that leaf folder infestation of rice occurred mainly during the heading to milky stages. The result showed that infestation of rice ear-head bug began during the panicle initiation stage and indicated a tendency to increase toward maturity. Phadke and Ghai (1994) observed that rice ear-head bug infestation occurred during the rice flowering stage. The result of this study revealed an abundance of grasshoppers from the transplanting to harvesting stages of the crops but was at its maximum at the tillering stage. Pathak and Khan (1994) found that grasshoppers attack crops at all stages and feed on the leaves and shoots, sometimes cutting the ear heads.

The results of this study revealed that an occurrence of yellow stem borers was observed throughout the crop season but was at its maximum at the tillering and milking stages of rice. Pathak and Khan (1994) reported that rice stem borers were evident regularly throughout the rice growing season and attacked plants from seedling to maturity stages. The abundance of rice hispa was higher at the early growth stages and did not occur at maturity stages of rice. Pathak and Khan (1994) reported that the maximum population of adults and grubs of rice hispas were found at the mid tillering stage.

In conclusion, the diversity of insects was observed in rice fields and was different at different locations and at different growth stages of rice. Most of the insects were found in both locations but some were observed only in one location; for example, leaf folders were only found in Chitwan, whereas rice hispas were only found in Lamjung.

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# 尼泊爾奇旺 (Chitwan) 及拉姆瓊 (Lamjung) 兩地區之水稻昆蟲調查

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## 摘　要

本研究主要目的在評估尼泊爾奇旺 (Chitwan) 及拉姆瓊 (Lamjung) 兩地區，水稻 Y 在不同生長期之害蟲豐度及多樣性。在兩種不同氣候因子下，水稻生長期調查害蟲種類的數據結果顯示，奇旺 (Chitwan)(22) 的昆蟲種類高於拉姆瓊 (Lamjung)(15)。昆蟲種類出現最多的時期，在奇旺地區是在孕穗期及抽穗期 (9)，而在拉姆瓊地區則是在分蘗期 (2)。在此兩地區，白水螟蛾 (*Nymphula depunctalis* Guenée) 在水稻分蘗期，發生的數量最多；然而異稻緣蝽 (*Leptocorisa acuta* (Thunberg)) 的捕獲率在水稻乳熟期及堅糊熟期最多。非洲稻蝗 (*Hieroglyphus banian* (Fabricius)) 在水稻移植到收割均可發現，但在兩地區的水稻分蘗期的發生數量最多。此外，整個水稻栽種期都可觀察到一點大螟 (*Scirpophaga incertulas* Walker)，不過在奇旺水稻的分蘗期及拉姆瓊水稻乳熟期的出現數量最多。瘤野螟 (*Cnaphalocrosis medinalis* Guenée) 只有在奇旺地區水稻孕穗期及抽穗期的出現數量最多；而鐵甲蟲 (*Dicladispa armigera* Oliver) 僅在拉姆瓊地區水稻的分蘗期的出現數量最多。水稻害蟲的物種豐富度 (abundance) 及在水稻的分蘗期、開花期及乳熟期達到最高數目，然後在稻穗成熟期下降；至於物種的多樣性 (diversity) 則是隨著作物發育的階段而波動，而在兩個地方的水稻的穀粒成熟階段最高。

**關鍵詞**：氣候因子、豐度、水稻發育期、昆蟲