

## Density, diversity and herbivory of aboveground insects in a grassland community of central Himalayan tarai region

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**Abstract:** Species richness, density, biomass and herbivory of aboveground insects were studied in a grassland community of central Himalayan tarai region from April 1999 to March 2001. A total of 31 plant species were recorded in the grassland and mean aboveground net primary production was 2815 KJ m<sup>-2</sup> yr<sup>-1</sup>. Fifty-nine insect species belonging 8 insect orders were recorded in the grassland. Most of these individuals were herbivores. The maximum density of insects was 7.4 m<sup>-2</sup> and the maximum biomass 1295 mg m<sup>-2</sup>. The Shanon-Wiener diversity index H' ranged from 1.32 to 1.44. Mean secondary net production due to herbivores was 47.9 KJ m<sup>-2</sup> yr<sup>-1</sup>. Herbivores consumed an average of 12.8% of the above ground primary production.

**Resumen:** En una comunidad de pastizal de la región tarai del centro de los Himalaya se estudiaron la riqueza de especies, la densidad, la biomasa y la herbivoría de insectos aéreos entre abril de 1999 y marzo de 2001. En total se registraron 31 especies de plantas en el pastizal y la producción primaria aérea neta promedio fue 2815 KJ m<sup>-2</sup> año<sup>-1</sup>. En el pastizal fueron registrados 59 especies de insectos pertenecientes a ocho órdenes. La mayoría de estos individuos fueron herbívoros. La máxima densidad de insectos fue 7.4 m<sup>-2</sup> y la biomasa máxima fue 1295 mg m<sup>-2</sup>. El índice de diversidad de Shannon-Wiener H' fluctuó entre 1.32 y 1.44. La producción secundaria neta promedio debida a los herbívoros fue 47.9 KJ m<sup>-2</sup> año<sup>-1</sup>. Los herbívoros consumieron en promedio 12.8% de la producción primaria aérea.

**Resumo:** A riqueza específica, densidade, biomassa e carácter herbívoro dos insetos na parte aérea de uma comunidade de pastagem na região "tarai" nos Himalaias centrais foram estudadas entre Abril de 1999 a Março de 2001. Registrou-se um total de 31 espécies de plantas na pastagem e uma produção média líquida de 2815 KJ m<sup>-2</sup> ano<sup>-1</sup>. Na pastagem registaram-se cinquenta e nove espécies de insetos pertencendo a 8 ordens. A maior parte destes insetos eram herbívoros. A densidade máxima de insetos foi de 7,4 m<sup>-2</sup> e a biomassa máxima de 1295 mg m<sup>-2</sup>. O índice de diversidade H' de Shanon-Wiener variou entre os 1,32 e os 1,44. A produção média secundária líquida devida aos herbívoros foi de 47,9 KJ m<sup>-2</sup> ano<sup>-1</sup>. Os herbívoros consumiram em média 12,8% da produção primária aérea.

**Key words:** Aboveground insects, central himalayan tarai region, density, diversity, grassland.

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## Introduction

Grasslands are well-established ecosystems, which support large and small herbivores. Among small herbivores, insects often constitute an important group of arthropods in terms of their density and biomass, and the extent of damage they cause to plants. Detailed studies on population density, biomass and energetics have been conducted in many temperate and tropical grasslands (Blummer & Diemer 1996; Gyllenberg 1969; Köhler *et al.* 1987; Smalley, 1960; Wiegert 1965; Wiegert & Petersen 1983). However, such studies in grasslands of central Himalayan tarai region in India are lacking. This study describes the species richness, population density and biomass, species diversity, secondary net production and insects herbivory in tarai region grassland.

## Materials and methods

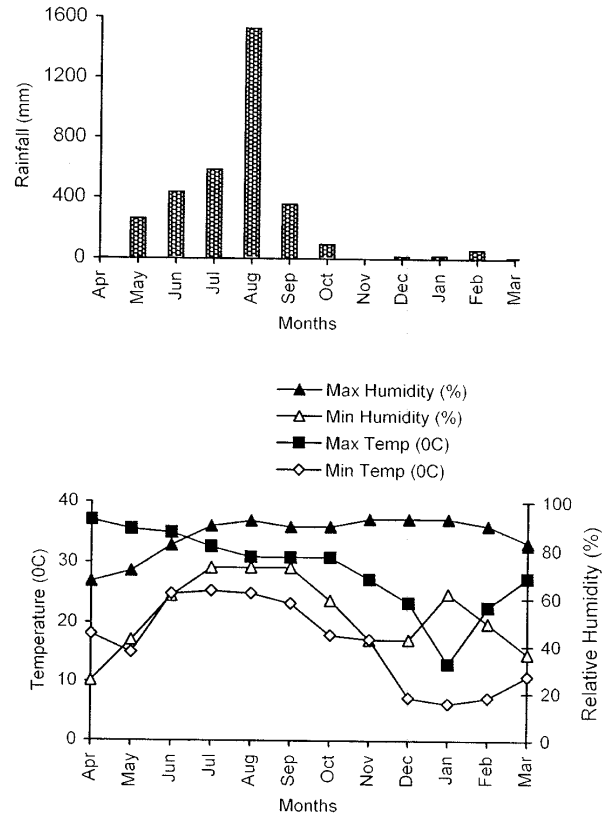
### *The study area*

The study site was 5 ha of grassland completely protected from human activity and grazing by livestock. The grassland is situated at Kichha (29° 55' N and 79° 41' E, 240 m altitude). The climatic data was obtained from G.B. Pant University of Agriculture & Technology, Pantnagar. The area had an average rainfall of 3370 mm. The mean maximum temperature ranges from 13 °C (January) to 37 °C (April) and the mean minimum temperature from 6.3 °C (January) to 25.3 °C (July) (Fig. 1).

### *Estimation of plant biomass, diversity and secondary productivity*

For the estimation of plant biomass, a total of 5 quadrats (50 cm x 50 cm) were harvested on each sampling date. Aboveground net primary production was determined by the trough analysis method for live plus recent dead plant material (Singh *et al.* 1975). According to this method, the sum of successive positive changes in the live biomass and the sum of positive changes in the standing dead biomass, which occurred concurrently with the live biomass, were totalled.

The population density of insects was estimated by the removal-trapping method (Kaushal & Vats 1984a). Cages, each with an area



**Fig. 1.** Climatic data for Kichha during April 1999 – March 2001.

of 1 m<sup>2</sup>, were constructed with an entrance (80 cm x 40 cm) on one side at 10 cm above ground level. Wire gauze (5 meshes cm<sup>-1</sup>) was fixed on all sides except on the ground surface. This mesh size prevented the escape of insects from the cages. Five cages were used at each sampling date. Sampling was done every 15 days, except in winter, when it was done monthly because the population density of insects was low.

Collected insects were oven-dried to constant weight at 60 °C for 72 h and the mass of each specimen determined. Insects were separated into species and individuals occupying different trophic levels i.e. herbivores, omnivores, saprophages, parasites and predators, on the basis of their habits. The insects were identified at Forest Research Institute, Dehradun and Agricultural Research Institute, New Delhi.

Species diversity  $H'$  (P) was calculated using Shannon & Wiener (1963) expression:

$$H'(P) = - \sum_{i=0}^S P_i \log P_i$$

where,  $P_i = \frac{n_i}{N}$ ;  $n_i$  is the number of species present

in the season; and  $N$  is the number of individuals,  $S$  denotes the number of seasons.

Secondary net productivity was calculated using Wiegert's (1965) expression:

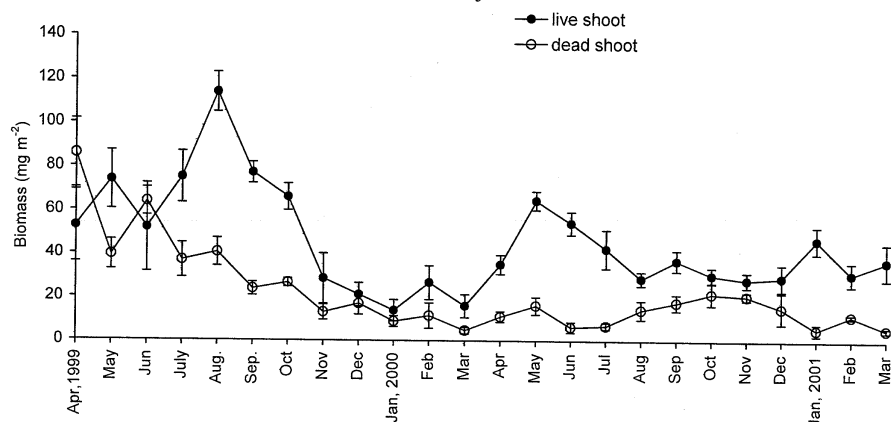
$$P = S \sum_{i=2}^n \frac{(N_i + N_{i-1})}{2} (W_i - W_{i-1})$$

where,  $N_i$  is the number of herbivores present at time  $i$ ,  $W_i$  is the mean weight per insect at time  $i$ ,  $i$  is the sampling time,  $S$  is the standing crop at time  $i=1$ . It was assumed that  $N_i \leq N_{i-1}$  and  $W_i \geq W_{i-1}$ . When  $W_i$  was less than  $W_{i-1}$ , production was considered to be zero.

#### Herbivory by insects

The impact of insects on vegetation was calculated by using weight-specific consumption determined in the laboratory (Kaushal & Joshi 1991), and the time series biomass data from the field. The total annual consumption was obtained by totalling the consumption for all seasons calculated as:  $C_s = B \times N \times C$ ; where,  $C_s$  = the seasonal consumption,  $B$  is the mean seasonal biomass and is calculated using Petruszewicz & Macfadyen (1970) expression:

$$B = \frac{\sum_{i=1}^k B_i}{K}$$



**Fig. 2.** Variation in live shoot and dead shoot biomass during April 1999 – March 2001 (vertical bars represent  $\pm$ SE).

where,  $B$  is the successive standing crop at time  $i$  and  $k$  is the number of sampling times,  $N$  is the number of days in a season during which insects were available and  $C$  is the weight-specific consumption.

## Results

### Primary production

A total of 31 plant species were recorded in the grassland. Live shoot of 28 species were present in the rainy season, 8 in the winter and 15 in the summer season.

The live shoot biomass increased through summer and finally reached the maximum during or after the rainy period in the first year but did not follow such pattern in the second year (Fig. 2). Grasses contributed most of the biomass. The increase in dead shoot biomass occurred 2-3 months later and was greatest in winter, when annual plants had senesced. Both live shoot and dead shoot biomass were much higher during April 1999 – March 2000 than during April 2000 – March 2001 because of more rainfall (3900 mm) during first year than (3360 mm) in second year. The aboveground net primary production was much higher ( $3829 \text{ KJ m}^{-2} \text{ yr}^{-1}$ ) during April 1999 – March 2000 than in April 2000 – March 2001 ( $1801 \text{ KJ m}^{-2} \text{ yr}^{-1}$ ) (Table 1).

### Secondary production

A total of 59 species of insects representing 30 families of 8 orders were collected. Of these, 29 species were recorded through both study years.

Maximum number of individuals and species belonged to Lepidoptera, whereas percent contribution varied for the remaining orders (Table 2).

Species richness was highest during summer and rainy periods and lowest during the winter (Table 3). Species richness was correlated

**Table 1.** Net aboveground primary production in grassland in different seasons.

Season	Net production (g m <sup>-2</sup> )	
	1999 – 2000	2000 - 2001
Rainy (July – October)	42.5	11.8
Winter (November – February)	15.4	0
Summer (March – June)	138.5	80.6
Annual	196.4	92.4
	(3829 KJ m <sup>-2</sup> yr <sup>-1</sup> )*	(1801 KJ m <sup>-2</sup> yr <sup>-1</sup> )*

\* Converted to joules by multiplying with 19.5 J mg<sup>-1</sup> (Kaushal & Vats 1984b).

**Table 2.** Number of species and individuals recorded for different insect orders and their percent contribution in the grassland during April 1999 to March 2001.

Taxonomic Group (orders)	April 1999 – March 2000				April 2000 – March 2001			
	Number of species	%	Number of individuals	%	Number of species	%	Number of individuals	%
Lepidoptera	17	34.7	180	55.6	14	41.1	89	58.2
Orthoptera	10	20.4	82	25.3	8	23.5	41	26.7
Coleoptera	7	14.3	10	3.0	4	11.8	5	3.2
Hymenoptera	7	14.3	28	8.6	4	11.8	12	8.0
Odonata	4	8.2	19	5.9	2	5.9	2	1.3
Hemiptera	2	4.1	3	1.0	2	5.9	-	-
Dictyoptera	1	2.0	1	0.3	-	-	-	-
Neuroptera	1	2.0	1	0.3	-	-	-	-
Total	49	100	324	100	34	100	153	100

**Table 3.** Total monthly variation in the species content of different taxa in the grassland during April 1999 – March 2001.

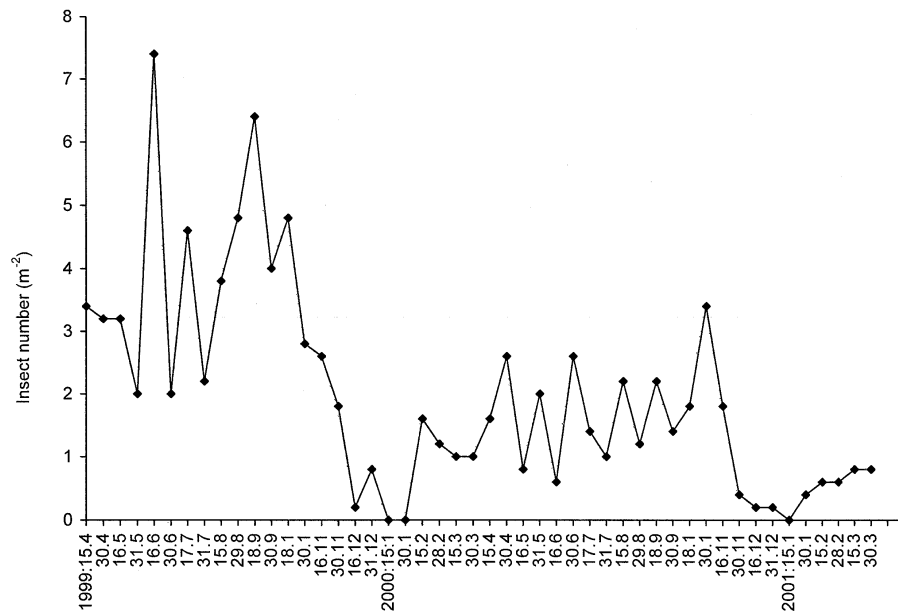
Taxon (Order)	April	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Orthoptera	3	2	9	7	6	3	2	1	1	-	-	1
%	12.5	22.2	47.3	41.2	28.6	18.8	12.5	7.1	25.0	-	-	12.5
Lepidoptera	9	5	6	6	9	8	9	9	2	1	7	5
%	50.1	55.6	31.6	35.3	42.8	49.9	56.2	64.3	50.0	100.0	70.0	62.5
Coleoptera	2	-	3	1	1	2	2	-	-	-	-	-
%	8.3	-	15.8	5.9	4.8	12.5	12.5	-	-	-	-	-
Hymenoptera	6	-	-	-	2	1	2	4	-	-	2	1
%	25.0	-	-	-	9.5	6.3	12.5	28.6	-	-	20.0	12.5
Hemiptera	2	-	-	-	-	2	-	-	-	-	1	-
%	8.3	-	-	-	-	12.5	-	-	-	-	10.0	-
Odonata	2	2	1	3	2	-	1	-	-	-	-	1
%	8.3	22.2	5.3	17.6	9.5	-	6.3	-	-	-	-	12.5
Dictyoptera	-	-	-	-	1	-	-	-	1	-	-	-
%	-	-	-	-	4.8	-	-	-	25.0	-	-	-
Neuroptera	-	-	-	-	-	-	-	-	-	-	-	-
%	-	-	-	-	-	-	-	-	-	-	-	-
Total	24	9	19	17	21	16	16	14	4	1	10	8

positively with maximum temperature ( $r = 0.466$ ;  $P \leq 0.01$ ,  $df = 24$ ), minimum temperature ( $r = 0.581$ ;  $P \leq 0.01$ ,  $df = 24$ ), rainfall ( $r = 0.335$ ;  $P \leq 0.05$ ,  $df = 24$ ), and live shoot ( $r = 0.571$ ;  $P \leq 0.01$ ,  $df = 24$ ).

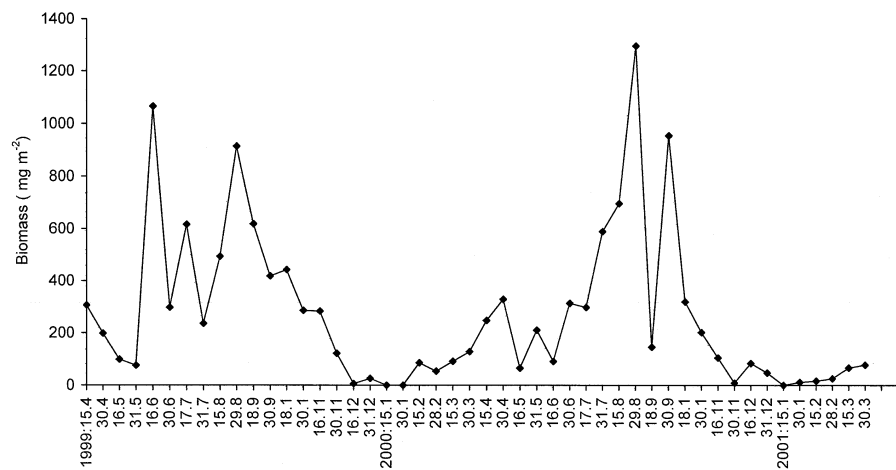
Considering the number of species collected, 72.4% were herbivores, 14.0% predators, 6.5% omnivores, 4.6% saprophages, 2.5% parasites. On the basis of number of individuals collected,

90.4% were herbivores, 6.1% predators, 1.4% omnivores, 1.1% parasites and 1.0% saprophages. Considering the biomass, 81.7% were herbivores, 8.0% omnivores, 5.6% saprophages, 4.1% predators and 0.6% parasites. Data on population density and biomass of insect fauna from April 1999 to March 2001 are depicted (Figs. 3 & 4).

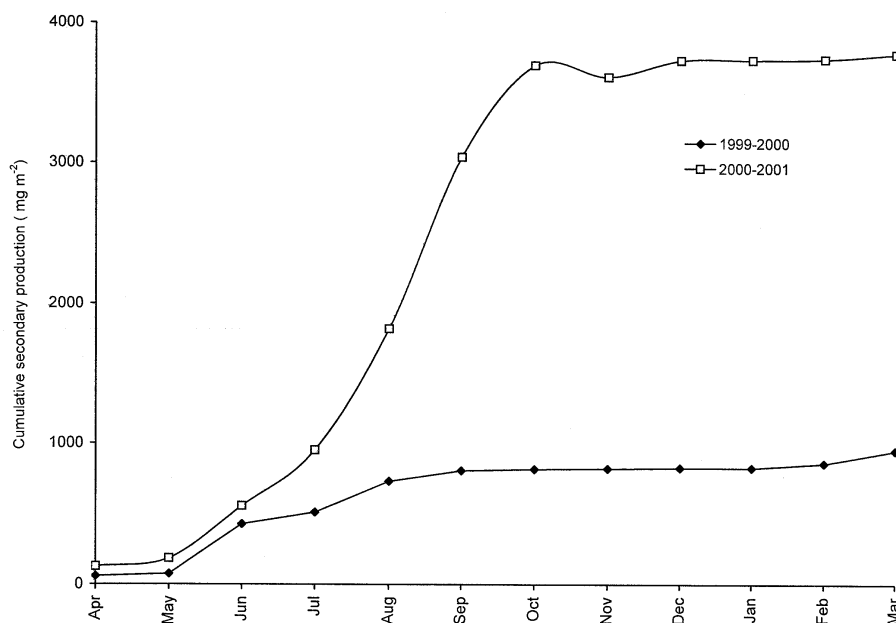
Strong interannual variations in population



**Fig. 3.** Variation in density of insect during April 1999 – March 2001; also shown are date, month of sampling.



**Fig. 4.** Variation in the biomass of insect during April 1999 – March 2001; also shown are date, month of sampling.



**Fig. 5.** Cumulative net secondary production of herbivores during April 1999 – March 2001.

density occurred: Density varied from zero (January) to 7.4 m<sup>-2</sup> (June) during April 1999 to March 2000; and from zero (January) to 3.4 m<sup>-2</sup> (October) during April 2000 to March 2001 (Fig. 3). Maximum number of insects was recorded during the rainy period and minimum during the

**Table 4.** Shannon-Wiener diversity index ( $H'$ ) of insect fauna in study site during April 1999 – March 2001.

Months	Period	
	April 1999 – March 2000	April 2000 – March 2001
April	1.43	1.41
May	1.40	1.38
June	1.37	1.41
July	1.41	1.43
August	1.42	1.40
September	1.37	1.39
October	1.43	1.32
November	1.44	1.38
December	1.35	1.41
January	-	1.41
February	1.37	1.43
March	1.41	1.44
Average	1.28	1.40

winter season. Total population density (64.8 m<sup>-2</sup>) during April 1999 to March 2000 was significantly more than during April 2000 to March 2001 (30.6 m<sup>-2</sup>).

Population density of insects was significantly positively correlated with maximum temperature ( $r = 0.527$ ;  $P \leq 0.01$ ,  $df = 24$ ), minimum temperature ( $r = 0.672$ ;  $P \leq 0.01$ ,  $df = 24$ ), rainfall ( $r = 0.226$ ;  $P < 0.5$ ,  $df = 24$ ), and live shoot ( $r = 0.713$ ;  $P \leq 0.01$ ,  $df = 24$ ).

Biomass of insects ranged from zero (January) to 1065 mg m<sup>-2</sup> (June) during April 1999 to March 2000, and from zero (January) to 1295 mg m<sup>-2</sup> (August) during April 2000 to March 2001 (Fig. 4).

The Shannon-Wiener diversity index  $H'$  varied from 1.35 to 1.44 during April 1999 to March 2000, and from 1.32 to 1.44 during April 2000 to March 2001 (Table 4). Since the diversity index is a function of both species richness and evenness, its similar values in both years can only be explained by a more even distribution of species during the study period.

Total secondary net production was 1010 mg m<sup>-2</sup> (22.2 KJ m<sup>-2</sup>) in April 1999 – March 2000, and 3774 mg m<sup>-2</sup> (75.5 KJ m<sup>-2</sup>) in April 2000 – March 2001 (Fig. 5). Mean secondary net production was

**Table 5.** Seasonal and annual consumption (KJ m<sup>-2</sup>yr<sup>-1</sup>) by herbivores in the grassland during April 1999 to March 2001.

Season	No. of days	Mean biomass* (mg insect <sup>-1</sup> )	Consumption** (KJ m <sup>-2</sup> )
April 1999-March 2000			
Summer (March – June)	122	68.8	56.8
Rainy (July – October)	123	119.5	99.4
Winter (November – February)	120	33.4	27.6
Total (KJ m <sup>-2</sup> yr <sup>-1</sup> )			183.8
April 2000 – March 2001			
Summer (March – June)	122	134.2	110.8
Rainy (July – October)	123	413.1	343.7
Winter (November – February)	120	104.8	85.1
Total (KJ m <sup>-2</sup> yr <sup>-1</sup> )			539.6
Average consumption (KJ m <sup>-2</sup> yr <sup>-1</sup> )			361.7

\* Mean biomass from field data.

\*\* Calculated by using energy values (22.4 J mg<sup>-1</sup>) considered after Kaushal & Vats (1984b) and weight-specific consumption (0.302 mg<sup>-1</sup> insect<sup>-1</sup>) after Kaushal & Joshi (1991).

2392 mg m<sup>-2</sup> (47.9 KJ m<sup>-2</sup>) during April 1999 – March 2001. In the present study, as a proportion of net primary production, secondary production was 1.7%. Herbivores ingested an average of 12.8% of the standing biomass of grass (Table 5).

## Discussion

The maximum insect density (7.4 m<sup>-2</sup>) recorded in present study is comparable with reported density of a sub-temperate grassland community (9.8 m<sup>-2</sup>) at Naukuchiatal (Kaushal & Joshi 1997) and grassland savanna Lamto (8.0 m<sup>-2</sup>; Gillon & Gillon 1974). However, it was lower than reports elsewhere; e.g. natural Tennessee grassland, 56.5 m<sup>-2</sup> (van Hook 1971); short grass prairie, Colorado, 144.9 m<sup>-2</sup> (Rotman & Capinera 1983); grassland community, Kurukshetra, 40.9 m<sup>-2</sup> (Kaushal & Vats 1984a). On the contrary, the biomass (1295 mg m<sup>-2</sup>) was comparable with most of the values reported elsewhere (natural Tennessee grassland, 1342 mg m<sup>-2</sup>; grassland at Savanna Lamto, 853 mg m<sup>-2</sup>; Gillon & Gillon 1974) but more than the values reported (333 mg m<sup>-2</sup>) for sub-temperate grassland community at Naukuchiatal in the region (Kaushal & Joshi 1997).

Extremely low and high temperature, rainfall and vegetation cover have been reported to influence the population density of insects (Nummelin 1996; Wardle & Barker 1997). Our study supports these contentions.

Shanon-Wiener Diversity Index H' recorded in the present study (1.0 - 1.44) falls in the reported range of other reported values (Armstrong 1995; Booij & Noorlander 1992; Clark 1999; Kromp 1989). Boiteau (1983) also reported that predatory insects resulted in low diversity of insects in the potato fields.

Secondary production by herbivores in this study amounted to 1.7% of the net primary production during the study period. This value falls in the range of 0.006 to 3% reported in other studies (Blummer & Diemer 1996; Kaushal & Joshi 1997; Kaushal & Vats, 1984b; Köhler *et al.*, 1987; Smalley 1960; van Hook 1971; Wiegert 1965).

The values of biomass consumed by herbivores (12.8%) were more than biomass consumed (0.4 – 10%) elsewhere (Köhler *et al.*, 1987; Riegert & Varley 1973; van Hook 1971) but less than the 30% consumption reported (Bailey & Riegert 1973; Blummer & Diemer 1996; Smalley 1960).

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