*Journal of Tropical Forest Science* 7(4): 521 - 531 (1995) 



# SEASONAL CHANGES IN SPECIES DIVERSITY, PHYTOMASS AND NET PRIMARY PRODUCTION IN A TEMPERATE GRASSLAND IN KUMAUN, CENTRAL HIMALAYA, INDIA

**Mukesh Joshi**

*Department of Botany, Kumaun University, Nainital - 263 002, (U.P.), India*

*Received February 1993*

**JOSHI, M. 1995. Seasonal changes in species diversity, phytomass and net primary production in a temperate grassland in Kumaun, Central Himalaya, India.** Species diversity, plant biomass and net primary productivity are presented for a temperate grassland of Kumaun, Central Himalaya, India. The species diversity declined from a maximum in September (2.5) to a minimum in December (1.7). The monthly live shoot biomass exhibited a unimodel growth pattern with peak live shoot biomass of 278 g m $^{-2}$ that was attained in September. The seasonal pattern showed that maximum (84%) above-ground production occurred during the rainy season and minimum (< 1%) during the winter season. The below-ground production was maximum (52%) during the winter season and minimum (11%) during the summer season. The annual net shoot production was 361 g m$^{-2}$ and total below-ground production was 193 g m$^{-2}$. Of the total input, 65% was chanelled to above-ground parts and 36% to below-ground parts. Transfer of live shoots to dead shoots compartment and dead shoots to litter compartment was 51% and 72% respectively. The total dry matter disappearance was 48% of the total input within the annual cycle. The grassland showed a net accumulation of surplus organic matter, indicating the seral nature of this grassland.

Keywords: Species diversity - biomass - net primary productivity - temperate grassland - turnover rate - litterfall

**JOSHI, M. 1995. Perubahan bermusim pada kepelbagaian spesies, fitojisim dan keluaran primer bersih dalam padang rumput beriklim sederhana di Kumaun, Himalaya Tengah, India.** Kepelbagaian spesies, biojisim tumbuhan dan daya pengeluaran primer bersih dibentangkan untuk padang rumput beriklim sederhana di Himalaya Tengah, India. Kepelbagaian spesies merosot dari maksimum pada bulan September (2.5) ke tahap minimum pada bulan Disember (1.7). Biojisim pucuk hidup setiap bulan mempamerkan pada pertumbuhan unimodel dengan sebanyak 278 g m$^{-2}$ biojisim dicapai pada puncak hidup di bulan September. Pola pertumbuhan bermusim menunjukkan bahawa pengeluaran atas tanah yang maksimum (84%) berlaku semasa musim hujan dan yang minimum (< 1%) berlaku semasa musim sejuk. Pengeluaran bawah tanah yang maksimum (52%) berlaku semasa musim sejuk dan yang minimum (11%) berlaku semasa musim panas. Pengeluaran pucuk bersih tahunan sebanyak 361 g m$^{-2}$ dan jumlah pengeluaran bawah tanah sebanyak 193 g m$^{-2}$. Dari keseluruhan input, 65% disalurkan pada bahagian-bahagian atas tanah dan 36% pada bahagian-bahagian bawah tanah. Pemindahan pucuk hidup ke bahagian pucuk mati dan pucuk mati ke bahagian serap masing-masing sebanyak 51% dan 72%. Kehilangan jumlah jirim kering adalah sebanyak 48% daripada keseluruhan input dalam kitaran tahunan. Padang rumput menunjukkan pengumpulan bersih jirim organik berlebihan yang menunjukkan sifat sere padang rumput ini.

* *Present address: G.B. Pant Institute of Himalayan Environment and Development, Kosi, Almora - 263 643, (U.P.), India*

## Introduction

The vegetation in the Himalaya ranges from tropical dry deciduous forest in the foot hills to alpine meadows (generally between 3000-4200 m elevation) above the timber line. The grasslands below 3000 m elevation have resulted from extensive clearing of natural forests due to cultivation, burning and heavy grazing pressure. Such grasslands have developed around human settlements and their areas are increasing with the receding forest boundaries (Joshi 1991). All these grasslands constitute feeding grounds for livestock of the inhabitants of the adjacent villages. The present study was undertaken to illustrate seasonal changes in species diversity, biomass and net primary production in a temperate grassland in Kumaun, Central Himalaya, India.

### *Study site*

The study was conducted in Kumaun Central Himalaya, India (29° 27' to 29° 29'N and 79° 23'to 79° 25'E ) at an average elevation of 1800 m.

The soil of the study area (0-30 cm depth) was residual, shallow and sandy in texture (sand 76%, silt 14% and clay 10%). Water holding capacity was 40%, bulk density 1.21 g $cm^{-3}$ and pH 5.9. Total nitrogen and organic carbon were 0.16% and 2.0% respectively (Joshi *et al.* 1994a).

### *Climate*

A meteorological station is located at an elevation of 2000 m near the study area. Of the total annual rainfall of 2441 mm, more than 75% occur from mid-June to mid-September. The mean daily maximum temperature varies from 12.5 °C (January) to 23.8 °C (May), and the mean minimum from 7.2 °C (December) to 17.0 °C (June) (Figure 1). Depending on climatic variations, the year is divisible into (1) a dry and warm summer season (March to May), (2) a wet and warm rainy season (June to September), and (3) a dry and cold winter season (October to February).

## Materials and methods

A grassland of an area of 2 ha was secured for the study. For biomass estimation, the herbaceous component was divided into the following compartments: live shoots, dead shoots, litter and below ground live component. Then live shoot compartment was separated species-wise. The shoot biomass was harvested as close to the ground as possible from ten randomly selected 1 × 1 m plots at 30-day intervals during September 1988 to September 1990, and no plot was harvested more than once. Litter was collected from each harvested plot and was washed through flotation. The samples were placed in perforated paper bags, brought to the laboratory, oven-dried at 80 °C till constant weight and weighed. The below-ground plant material was collected from one monolith (25 × 25 × 30 cm) from each harvested plot, subsequent to above-ground components. The monoliths were brought to the laboratory and washed with a fine jet of water using 2 mm and 0.5 mm mesh screens. The samples were dried at 80 °C to constant weight and weighed. Species diversity (H) was calculated on the basis of live shoots biomass as described by Smith (1980), viz.

$$H = 3.322\ [\log_{10} N - (1/N \sum N_i \log_{10} N_i)]$$

Where N is the total shoot biomass and $N_i$ is the shoot biomass of species i, both in g $m^{-2}$.

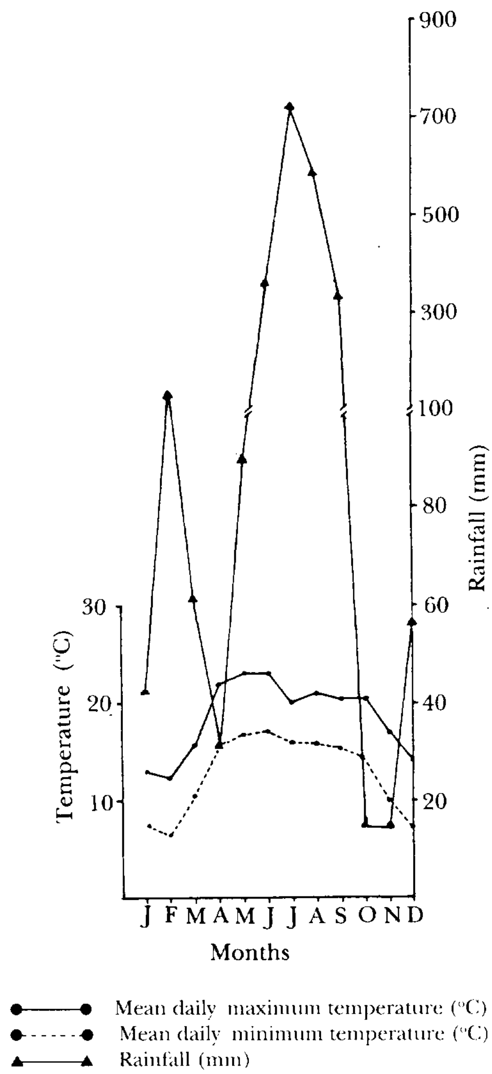


**Figure 1.** Climatic diagram (average of three years, i.e. 1988 - 1990) for the study area

Net above-ground primary production (ANP) was determined as sum of positive changes in above-ground biomass plus mortality (Singh & Yadava 1974). Dry matter which had been produced and disappeared within a sampling interval could not be estimated in the present study. Thus, the production estimate was considered as minimum. The below-ground net production (BNP) was estimated by summation of the positive changes in the below-ground biomass (Singh & Yadava 1974). Difficulties and errors involved in the estimation of BNP are discussed by several authors (Schuuroman & Goedewaagan 1964, Head 1970, Sims & Singh 1978b).

Turnover rate of below-ground biomass was calculated using the formula as proposed by Dahlman and Kucera (1965):

$$\text{Turnover} = \frac{\text{Below-ground net production}}{\text{Maximum below-ground biomass}}$$

Net accumulation and disappearance rates for dry matter were calculated only for one year (September 1988 to September 1989).

Biomass values for September 1988 were taken as initial values. The rates were calculated following Singh and Yadava (1974), and Sims and Singh (1978c) as follows:

- Transfer of live shoots to dead shoots was calculated by summation of the positive change in dead shoots on successive sampling date;
- Transfer of dead shoots to litter was calculated by summation of negative changes in the dead shoots;
- Disappearance of litter (LD) was calculated as:
  LD = (initial amount of litter + litter production) - (amount of litter at the end);
- Disappearance of below-ground biomass (BD):
  BD = (initial below-ground biomass) + (BNP) - (final belowground biomass);
- Total disappearance (TD):
  TD = LD + BD

## Results

The data of September, December and April (Table 1) representing the rainy, winter and summer seasons respectively indicated that during the rainy and summer seasons, *Cymbopogon distans* (grass) was the dominant species with maximum density and IVI (Table 1). However, during the winter season, the grassland was dominated by *Dicliptera roxburghiana.* The total density (individuals $m^{-2}$) was maximum (1235) in September and minimum (26) in December.

**Table 1.** Herbaceous vegetation in the rainy season, winter season and summer season as analysed in September, December and April respectively

| Growth forms/species | Rainy season (September) | | Winter Season (December) | | Summer season (April) | |
|---|---|---|---|---|---|---|
| | Density (individuals $m^{-2}$) | IVI* | Density (individuals $m^{-2}$) | IVI* | Density (individuals $m^{-2}$) | IVI* |
| Tall forbs | | | | | | |
| *Craniotome furcata* | 1.6 | 8.1 | - | - | - | - |
| *Gnaphalium hypoleucum* | 2.4 | 9.0 | 0.8 | 14.4 | - | - |
| *Scutellaria angulosa* | 6.0 | 12.6 | 3.2 | 60.2 | 6.0 | 39.2 |
| *Swertia cardata* | 0.8 | 8.6 | - | - | - | - |
| Short forbs | | | | | | |
| *Dicliptera roxburghiana* | 2.8 | 13.5 | 7.2 | 97.9 | 15.6 | 54.3 |
| *Micromeria biflora* | 11.2 | 14.9 | 12.4 | 81.6 | 16.0 | 41.6 |
| *Reinwardtia indica* | 2.0 | 10.7 | 2.0 | 47.8 | 2.8 | 14.7 |
| Cushion and spreading forbs | | | | | | |
| *Oxalis corniculata* | 2.0 | 7.7 | - | - | - | - |
| Grasses and sedges | | | | | | |
| *Arthraxon lanceolatus* | 68.8 | 21.8 | - | - | - | - |
| *Arundinella nepalensis* | 16.8 | 10.5 | - | - | - | - |
| *Chrysopogon serrulatus* | 456.0 | 79.2 | - | - | 9.4 | 67.4 |
| *Cymbopogon distans* | 664.8 | 103.4 | - | - | 16.4 | 82.5 |

* Importance value index

### *Biomass and production*

The monthly biomass of live shoots, dead shoots, litter and below-ground compartments is illustrated in Figure 2. Analysis of variance (ANOVA) (Snedecor & Cochran 1975) indicated significant differences in the biomass of live shoot, dead shoot, litter and below-ground component between months ($p < 0.01$ in all cases) but not between the years. The following description on biomass and productivity is based on the average of two years.

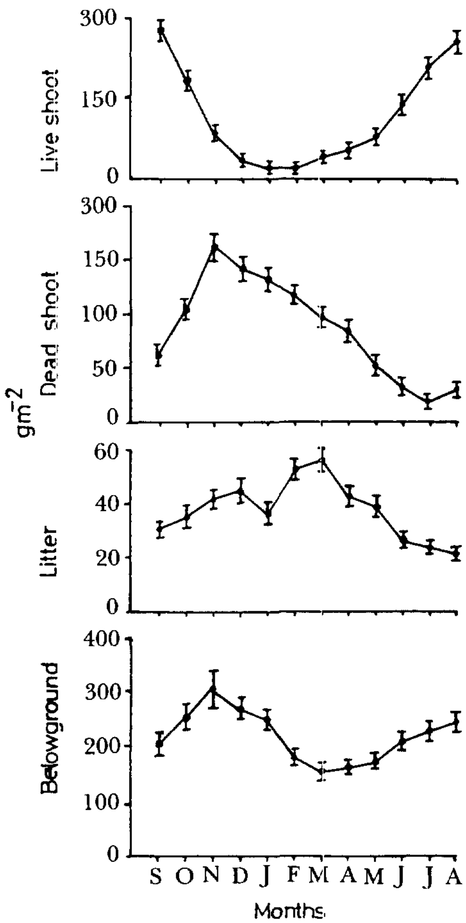


**Figure 2.** Monthly biomass of different above and below-ground compartments during the study period. Vertical bars represents ± 1 SE

The biomass of live shoots ranged from 15 to 278 g $m^{-2}$ in different months. The live shoot biomass decreased from September (peak) to January (minimum) whereafter it increased gradually during the summer season and then rapidly with the commencement of the rainy season.

The amount of live shoots biomass was positively related to monthly rainfall and temperature as follows:

$$y_1 = 57.142 + 0.282\ x_1 \ (r = 0.719,\ p < 0.01)$$
$$y_2 = -120.273 + 15.020\ x_2 \ (r = 0.633,\ p < 0.05)$$

Where $y_1$ and $y_2$ are the live shoot biomass (g $m^{-2}$); and $x_1$ and $x_2$ are the monthly rainfall (mm) and temperature in (°C) respectively.

The dead shoot biomass ranged from 24 to 167 g $m^{-2}$. The dead shoot biomass increased from September to attain peak in November, thereafter it declined continuously in subsequent months.

The litter biomass ranged from 21 to 56 g $m^{-2}$. The litter biomass increased continuously from September to March and declined in subsequent months.

It is apparent from the foregoing that the above-ground biomass structure continuously changes with the change in season. During winter and early summer biomass production was primarily of dead tissues, and during rainy season from June to September, of live tissues.

The below-ground biomass ranged from 153 to 308 g $m^{-2}$. The minimum value was found in March and maximum in November. The below-ground biomass increased from September to November whereafter it decreased until March, and increased again in subsequent months.

The above-ground net primary production was 361 g $m^{-2}$. The seasonal pattern showed that maximum production occurred during the rainy season (84%) and minimum during the winter season (<1%) (Table 2). The total net below-ground production was 193 g $m^{-2}$. Maximum root production occurred in the winter season (52%) and minimum in the summer season (11%). Below-ground production contributed about 35% to the total net production of 554 g $m^{-2}$ in this grassland (Table 2).

**Table 2.** Seasonal above-ground net production (ANP), below-ground net production (BNP) and total net production (TNP). All the values are in g $m^{-2}$ and the values in parentheses are per cent of total annual

| Season | Above-ground net production (ANP) | Below-ground net production (BNP) | Total net production (TNP) |
|---|---|---|---|
| Rainy (June-September) | 301.2 (84) | 71.2 (37) | 372.4 (67) |
| Winter (October-February) | 1.0 (0.3) | 100.6 (52) | 101.6 (18) |
| Summer (March-May) | 58.9 (16) | 21.6 (11) | 80.5 (15) |
| Annual | 361.1 | 193.4 | 554.5 |

ANP, BNP and TNP are significantly different (p<0.01) in the rainy season from the summer and winter seasons.

## Discussion

Though individual species varied in growth phenologies, their cumulative effects resulted in an increase of community biomass from January to September. In most herbs, growth began in June with the advent of monsoon rains. That explains why most increment in biomass of the community was during the rainy season, when temperature was optimal (the mean monthly temperature being 18 - 23 °C) and, more importantly, soil was consistantly moist. The decline in temperature and soil moisture brought about a cessation in new growth and gradual decline in the live shoot biomass during winter months.

The botanical composition of the community biomass changed as the growing season advanced (Table 3). The number of species and plant diversity declined from maximum in September to minimum in December (Table 3). Most of the species in this grassland commence and complete their growth cycle during the rainy season (Joshi *et al.* 1994 b). A large number of species contributed significantly to shoot biomass. If the definition of dominants is arbitrarily narrowed down to species contributing > 1% to total above-ground production, then the number of dominants would be 11 for the present grassland. Kumar and Joshi (1972) recorded 12 to 18 such dominants in a semi-arid grassland, and Singh and Yadava (1974) found 17 dominants in a dry sub-humid tropical grassland at Kurukshetra. Ram *et al.* (1988) and Sah and Ram (1989) have reported 14 and 12 species respectively from temperate grasslands of India.

**Table 3.** Live shoot biomass of different growth forms as per cent of community biomass, number of species and species diversity in rainy season, winter season and summer season as measured in September, December and April respectively

| | Rainy season (September) | Winter season (December) | Summer season (April) |
|---|---|---|---|
| Tall forbs | 9 | 24 | 13 |
| Short forbs | 10 | 76 | 17 |
| Cushion and spreading frobs | 1 | - | - |
| Grasses and sedges | 81 | - | 70 |
| Number of species | 12 | 5 | 6 |
| Species diversity | 2.5 | 1.7 | 1.9 |

The peak growth rate of net accumulation in live shoot biomass is an index of net photosynthetic efficiency of vegetation under given environmental condition (Ram *et al.* 1989); it also indicates when optimum growing conditions occur at various sites (Sims & Singh 1978a). In the tropical grasslands of India the peak growth rates may be as high as 14 - 15 g $m^{-2}$ $day^{-1}$ occurring towards the end of the monsoon season in September (Singh & Yadava 1974, Gupta & Singh 1982b). The peak growth rate of live shoot biomass (2.4 g $m^{-2}$ $day^{-1}$) in the present grassland is within the range (1.2 to 6.5 g $m^{-2}$ $day^{-2}$) given by Sims and Singh (1978a) for various temperate grasslands of the Western North America.

The accumulation of biomass in below-ground parts showed a bi-modal pattern of growth and a second peak in November. Such bi-modal patterns of below-ground biomass have also been reported by Singh and Krishnamurthy (1981) and Sah and Ram (1989) from different Indian grasslands. The turnover of below-ground biomass in the present grassland is rather rapid with as much as 62% of below-ground biomass being replaced each year.

There is a wide range of the above-ground production in the temperate grasslands and the values range from 51 to 679 g m$^{-2}$ (Sims & Singh 1978b, Singh *et al.* 1983). The estimated value of above-ground production in the present study (361 g m$^{-2}$) is within this range, and lower than the value (1184 g m$^{-2}$) reported by Sah and Ram (1989) for a temperate grassland of Central Himalaya. The above-ground production in this study was higher than the below-ground production, and it was higher than the values reported by Kumar and Joshi (1972) and Sah and Ram (1989) for alpine and semi-arid grasslands respectively, and lower than the values reported for a tropical grassland (Singh & Yadava 1974).

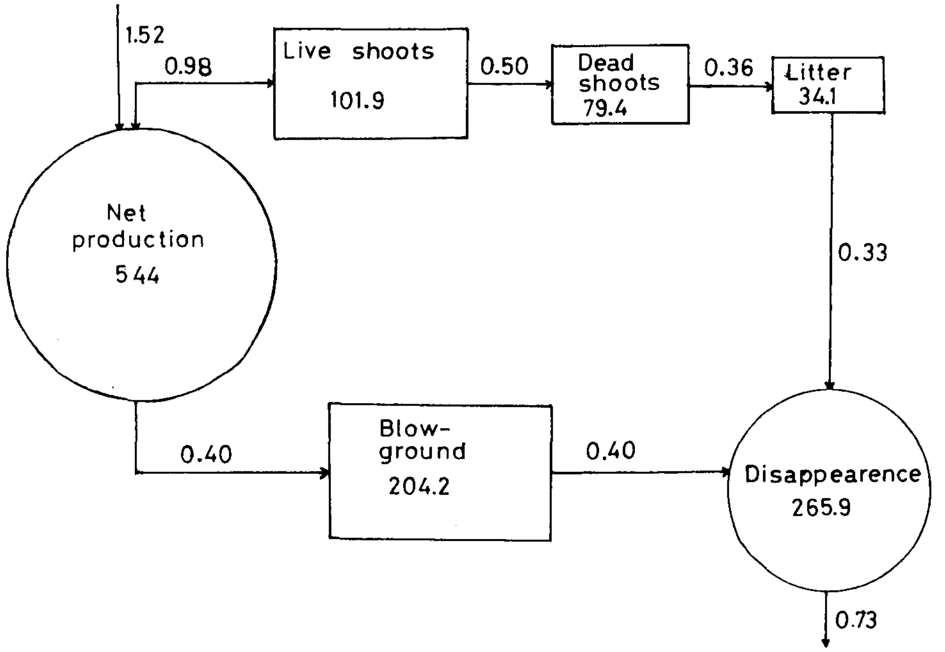


**Figure 3.** Diagram depicting net dry matter flow through diferent compartments. Number in boxes are the mean standing crop (g m$^{-2}$ y$^{-1}$); number in circle are total net primary production and disappearance; number on the arrows are net flux rates in g m$^{-2}$ day$^{-1}$

The net accumulation and disappearance of dry matter in the present grassland are shown in Figure 3. The season-long mean biomass values of live shoots, dead shoots, litter and below-ground parts are given in boxes. The net flux rates are indicated on arrows. Of the total input of 1.52 g m$^{-2}$ day$^{-1}$ into the system, about

65% was chanelled to the above-ground parts and 35% to the below-ground parts. Transfer of live shoots into dead shoots compartment and that of dead shoots to litter compartment was 51% and 72% respectively. The rate of disappearance of litter was 33 g $m^{-2}$ $day^{-1}$ (i.e. 92% of the litter input) and that of below-ground was 0.40 g $m^{-2}$ $day^{-1}$ (100% of the BNP). The sum of these values, which represents the total output, was 0.73 g $m^{-2}$ $day^{-1}$, which was 48% of the total input (TNP). Thus the present grassland showed a net accumulation of surplus organic matter, indicating the seral nature of the grassland. This situtation is similar to the successional tropical grassland described by Gupta and Singh (1982a, b), where accumulation of surplus organic matter which could result in the advancement of the seral grassland to woodland condition is rather massive.

## Acknowledgements

I thank S.P. Singh and Y.S. Rawat, Department of Botany, Kumaun University, Nainital, for their valuable guidance and useful suggestions.

## References

BOR, L.N. 1960. *Grasses of Burma, Ceylon, India and Pakistan.* Pergamon Press, London. 767 pp.

DAHLMAN, R.C. & KUCERA, C.L. 1965. Root productivity and turnover in native prairie. *Ecology* 46: 84 - 89.

GUPTA, S.R. & SINGH, J.S. 1982a. Carbon balance of a tropical successional grassland. *Acta Oecologia, Oecologia Generalis* 3 : 459 - 467.

GUPTA, S.R. & SINGH, J.S. 1982b. Influence of floristic composition on the net primary production and dry matter turnover in a tropical grassland. *Australian Journal of Ecology* 7 : 363 -374.

HEAD, G. C. 1970. Methods for the study of production in root systems. Pp. 151-157 in *Methods of Study in Soil Ecology* (Sd. by J. Phillipson). UNESCO, Paris.

JOSHI, M. 1991. Seasonal pattern of cattle and goat grazing and its impact on Central Himalayan grazinglands. Ph.D. thesis, Kumaum University, Nainital (India). 209 pp.

JOSHI, M., SINGH, S.P. & RAWAT, Y.S. 1994 a. Analysis of grazingland vegetation of banj oak (*Quercus leucotrichophora* A. Camus) - chir pine (*Pinus roxburghii* Sarg.) forest zone in Central Himalaya. *Range Management & Agroforestry* 15(1) : 1 - 9.

JOSHI, M., SINGH, S. P. & RAWAT, Y. S. 1994b. Plant forms and seasonality of leaves in herb layers of sites with varying levels of deforestation. *Journal of Tropical Forest Science* 6(4): 508 - 522.

KUMAR, A. & JOSHI, M.C. 1972. The effects of grazing on structure and productivity of the vegetation near Pilani, Rajasthan, India. *Journal of Ecology* 60 : 665 - 674.

RAM, J., SINGH, J. S. & SINGH, S. P. 1989. Plant biomass, species diversity and net primary production in a Central Himalayan high altitude grassland. *Journal of Ecology* 77 : 456 - 468.

SAH, V.K. & RAM, J. 1989. Biomass dynamics, species diversity and net primary production in a temperate grassland of Central Himalaya, India. *Tropical Ecology* 30(2) : 294 - 302.

SCHUUROMAN, J. J. & GOEDEWAAGAN, M.A.J. 1964. *Methods for the Examination of Root Systems and Roots.* Centre for Agricultural Publications and Documents, Wageningen.

SIMS, P.L. & SINGH, J.S. 1978a. The structure and function of ten Western North American grasslands. II. Inter-seasonal dynamics in primary producer compartments. *Journal of Ecology* 66 : 547 - 572.

SIMS, P. L. & SINGH, J. S. 1978b. The structure and function of the ten Western North American grasslands. III. Net primary production, turnover, and efficiencies of energy capture and water use. *Journal of Ecology* 66 : 573 - 597.

SIMS, P. L. & SINGH, J. S. 1978c. The structure and function of ten Western North American grasslands. IV. Compartmental transfer and system tranfer functions. *Journal of Ecology* 66 : 983 - 1009.

SINGH, J. S. & KRISHNAMURTHY, L. 1981. Analysis of structure and function of tropical grassland vegetation of India. *Indian Review of Life Sciences* 1 : 225 - 270.

SINGH, J. S., LAUENROTH, W. K., HEITSCHMIDT, R.K. & DODD, J. L. 1983. Structural and functional attributes of the vegetation of Northern Mixed Prairie of North America. *Botanical Review* 49 : 117 - 149.

SINGH, J. S. & YADAVA, P.S. 1974. Seasonal variation in composition, plant biomass, and net primary productivity of a tropical grassland at Kurukshetra, India. *Ecological Monographs* 44 : 351 - 376.

SMITH, R.L. 1980. *Ecology and Field Biology*. Harper and Row Publishers, New York.

SNEDECOR, G.W. & COCHRAN, W.G. 1975. *Statistical Methods*. Oxford and IBH Publishing Company, New Delhi. 593 pp.