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Biomass Structure and Dry Matter Dynamics in a Fire Influencing Montane Subtropical Humid Grassland, Western Ghats, Southern India

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ABSTRACT : The biomass structure for three major components viz., the dominant grass, *Chrysopogon zeylanicus* Thw., the 'other grasses' and the 'remaining species' and dry matter dynamics for total community were studied over a period of one year in an annual fire influenced subtropical humid grassland community in Western Ghats, India. The biomass of aboveground, belowground and litter compartments were high as in other humid grasslands and generally have positive correlation with rainfall, rainy days and relative humidity with the exception of litter parts. The above and belowground net primary productions (4,561 and 722 g/m^2, respectively) were also higher and were comparable with other humid tropical grasslands. The turnover of organic matter was rapid. Of the total input of 14.47 g/m^2 into the system, about 86.3% was allocated to above ground parts and 13.7% to below ground parts. The total disappearance was 2.56 g/m^2 and it was accounted to be 17.68% of the total output. The net surplus of dry matter (82.32%) in the post fire community indicates that the grassland was maintained in a seral stage. Hence it is suggested that prescribed burning may keep this ecosystem in a highly productive and seral stage.

Key words : Biomass, *Cyrysopogon zeylanicus*, Fire, Grassland, Southern India, Western Ghats

INTRODUCTION

Grasslands in India occupy ca. 39.8 per cent (12.12 million ha) of the total reporting area (Singh 1987). The grasslands of peninsular India occur under the stress of severe biotic conditions such as annual burning, overgrazing, cutting, conversion into agricultural lands and plantations (Chinnamani 1981). Fire has been advocated as an important tool in shaping the structural and functional attributes of grasslands (Scifres 1980, Paulsamy *et al.* 1995). Effect of fire on grasslands is largely determined by season of burn, size of plant, amount of dead material, growth form, species, precipitation and whether it is an annual or perennial (Wright 1985). Ecological work on fire influenced grassland communities of Western Ghats, India are limited. Indeed no information is available on the ecology of post fire grassland communities of Western Ghats in terms of biomass structure, production and dynamics of dry matter. Hence the present study aims to know the changes in biomass, net primary production and system transfer functions in a humid, annual summer fire-influencing, *Chrysopogon zeylanicus*, dominated grassland of Grass Hills ecosystem, Western Ghats, India.

STUDY AREA

Study area Grass Hills lies in Anaimalais, Western Ghats (10° 32′ 8″ N and 77° 4′ 23″ E) at an elevational range of 1,650 to 2,100 m above m.s.l. Annual fire, an integral part of this ecosystem usually occurs during early summer (later half of February through March) and is shortly followed by adequate rainfall (Wilson, 1964). The climatic factors of the study area during the study period are given in Fig.1. The temperature ranges from 15 to 32°C (Fig. 1).

Usually November to February is a dry season and the rain starts from March. The habitat is humid due to the frequent and heavy rainfall of ca. 3,000 mm/year. The relative humidity ranges between 64 and 82%. Since the Grass Hills occupy the highest range of hills in Anaimalais, it is subjected to high wind velocity during south-west monsoon (June through August). The soil is black, loose, loamy, shallow and acidic.

The vegetation is dominated by a pernnial grass, *Chrysopogon zeylanicus* and is associated with 14 other grasses, 2 sedges, 17 forbs and a fern (Paulsamy 1992). *C. zeylanicus* is, highly palatable for wild animals (Chinnamani 1981). Rich

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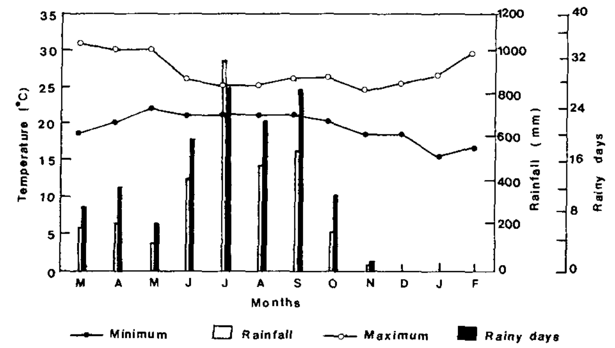

Fig. 1. Monthly rainfall, rainy days and mean minimum and maximum temperatures during the study period in Grass Hills, Western Ghats, Southern India.

variety of wild animals like sambar, Nilgiri tahr, great Indian gaur, lion tailed monkey, panther and birds like great Indian hornbill are also inhabiting this ecosystem (Wilson 1964).

METHODS

Five replicates of ca. 2 ha grassland were selected after the occurrence of surface fire during the third week of February, 1988. Harvest method (Milner and Hughes 1968) was used for the estimation of biomass and the optimum quadrat size, l $\times$ l m was obtained through the species area curve method (Greig-Smith 1964). Ten quadrats were sampled randomly during the last week of every month from March, 1988 to February, 1989. Harvested samples were sorted out into three major components viz., the dominant grass, *C. zeylanicus*, the 'other grasses' and the 'remaining species'. Each component was further separated into the compartments viz., live shoots and dead shoots. The collected litter was also separated into the above said three components. For the estimation of belowground biomass, 5 monoliths (25 $\times$ 25 $\times$ 30 cm^3) were excavated in the harvested plots. The monoliths were soaked in water for few hours and then washed in water carefully. The respective biomass values were determined after oven drying the samples at 80°C until constant weight.

The aboveground net primary production (ANP) was determined by summing up positive changes in biomass plus mortality method (Billore and Mall 1977). Belowground net primary production (BNP) and litter production were obtained by summation of positive increments of the respective biomass (Dahlaman and Kucera 1965). Net accumulation and disappearance rates of dry matter were estimated by the methods of Singh and Yadava (1974).

i. Transfer of live shoot to dead shoot was calculated by the summation of positive changes in the dead shoots on successive sampling dates.
ii. Transfer of dead shoot to litter (L) was calculated by the summation of negative changes in the dead shoots.
iii. Disappearance of litter (LD) = Initial litter biomass + Litter production - Final litter biomass.
iv. Disappearance of belowground biomass (BD) =Initial belowground biomass + BNP - Final belowground biomass.
v. Total disappearance (TD) = (LD) + (BD)

The turnover was calculated by following the method of Dahlmann and Kucera (1965). 'System transfer functions' were computed by the method of Singh and Yadava (1974).

RESULTS AND DISCUSSION

Changes in monthly biomass of live shoots, dead shoots, belowground and litter parts are shown in Fig. 2. Generally, above 60% of the standing crop biomass in the community, at all time for all compartments, was shared by the dominant grass, *C. zeylanicus*. Enhancement of tillering in the perennial grass, *C. zeylanicus* after fire may perhaps be a reason for the increased biomass of the said component (Paulsamy *et al.* 1995).

The standing crop biomass of the live shoots of the dominant grass, *C. zeylanicus,* was between 109.06 and 732.20g/m^2 during the study period. The 'other grasses' and the 'remaining species' varied between 24.74 and 429.46 g/m^2 and 8.22 and 451.60g/m^2, respectively (Fig. 2). All components during early months generally registered sharp increase in live shoot biomass which then declines until the end of the study period. However, the dominant grass, *C. zeylanicus,* showed another peak during December as in many humid grassland communities (Singh and Krishnamurthy 1981). Since the community was denuded by fire before the commencement of the study (February), fresh live shoots were produced in the post fire community during early months which declined after the completion of vegetative growth. Singh and Krishnamurthy (1981) opinioned that the peak in live shoot biomass is followed by decline and it is mainly due to the transfer of live shoots into standing dead shoots and litter.

The changes in dead shoot biomass of all the three components are exhibited in Fig. 2. For the dominant grass, the biomass ranged between 133.82 and 1,211.48 g/m^2, The biomass of 'other grasses' and the 'remaining species' were between 59.40 and 531.38 g/m^2 and 33.42 and 311.46 g/m^2 respectively. In the early stages the regenerated community from fire destruction was mainly composed of live shoot biomass and after the completion of vegetative growth within 3-4 months, they were transferred to dead shoots. Hence the dead shoot biomass lower in initial period was progressively increased and attained the maximum during the month of September. Similar pattern of dead shoot biomass contribution was already reported in the humid grasslands of northern India (Choudhary 1972, Trivedi

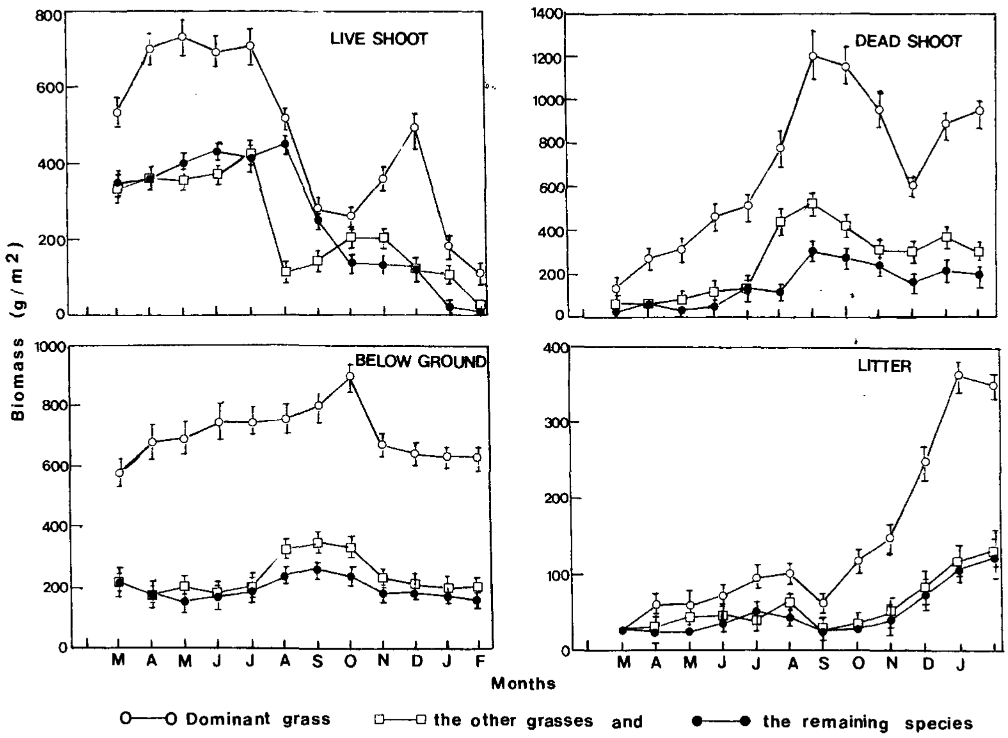

Fig. 2. Monthly changes in biomass of various compartments in Grass Hills, Western Ghats, Southern India. Vertical bars represent ±SD. The points lacking vertical bars have the SD of < 5.

and Mishra 1979).

The change in litter biomass is presented in Fig. 2. The standing crop litter biomass of the dominant grass varied between 24.54 and 350 g/m². The 'other grasses' and the 'remaining species' registered the biomass between 27.08 and 130.20 g/m² and 27.50 and 125.20 g/m², respectively. The biomass of litter increased from the post monsoon period (December through February) because of the transfer from live shoot compartment due to senescence and mortality of the herbage. The change in litter compartment generally follw the change in the standing dead compartment (Singh and Joshi 1979).

The dominant grass, *C. zeylanicus* contributed over 50% of the belowground biomass structure of the community. The belowground biomass also registered notable increases during rainy months as in live shoot (Fig. 2). The peak belowground biomass was occurred after the attainment of peak live shoot biomass. Trlica and Singh (1979) and Gupta (1987) explained that this may be due to a greater amount of assimilate transfered to roots concomitant with or succeeding the maturity of shoots Generally, the aboveground and belowground biomass of the community is positively correlated with rainfall, rainy days and relative humidity of the habitat (Table 1). The temporal variation exhibited in the attainment of peak biomass on different grasslands seems to be related to the quantity and frequency of rainfall (Singh and Krishnamurthy 1981). Further, it was already reported that the relative humidity is a primary environmental factor that controls the development of Grass Hills ecosystem (Paulsamy *et al.* 1996). On the other hand, the standing crop biomass of litter compartment is negatively correlated with temperature, rainfall, rainy days and relative humidity (Table 1). Along with high temperature the summer months of Grass Hills are also characterized by adequate and frequent rainfall which promoted the growth of green shoots only. Already the accumulated litter was completely burnt by the earlier summer fire and hence the litter biomass increased only in the subsequent months and attained peak during winter (December through February). Unfavourable climatic factors (least or no rainfall) for litter decomposition during winter may also be accounted for higher litter biomass for this period (Agarwal and Goyal 1987).

The total ANP was 4,561 g · m^{-2} · yr^{-1} (Table 2) and is comparable with the production of humid grasslands of Varanasi, India (Singh 1972) and Kundha India (Senthilkumar *et al.* 1998). The higher ANP in the post fire community of Grass hills is possibly due to the enhancement of tillering of perennials by summer fire (Paulsamy *et al.* 1997). Further, the removal of litter by fire has a stimulatory effect on current year growth (Britton *et al.* 1987). Generally, the prevailing occurrence of high humidity and frequent rainfall in this ecosystem may prove that water is not a lim-

Table 1. Correlation coefficients of the respective community vs climatic factors during the study period

Compoent	Temperature (℃)	Rainfal (mm)	Rainy days	Relative humidity (%)
Aboveground biomass				
Dominant grass	-0.309	0.310	0.378	0.527
'Other grasses'	-0.144	0.535	0.638*	0.563
'Remaining species'	0.478	-0.158	0.934*	0.740
Total community	-0.053	0.580	0.677*	0.681*
Belowground grass				
Dominant grass	-0.402	0.323	0.537	0.574
'Other grasses'	-0.055	0.244	0.412	0.184
'Remaining species'	0.021	0.399	0.520	0.240
Total community	0.045	0.403	0.569	0.424
Litter biomass				
Dominant grass	-0.768*	-0.518	-0.670*	-0.410
'Other grasses'	-0.642*	-0.316	-0.628	-0.402
'Remaining species'	-0.670*	-0.365	-0.547	-0.387
Total community	-0.734*	-0.535	-0.646*	-0.409

* $P > 0.05$

Table 2. Comparison of annual net primary production and annual rainfall of the Grass Hills ecosystem with the data from literature

Places	ANP[1] (g/m^2)	BNP[2] (g/m^2)	TNP[3] (g/m^2)	Rain-fall (mm)	Source data
Pilani	217	61	278	391	Kumar & Joshi (1972)
Kurukshetra	2,407	1,131	3,538	790	Singh & Yadava (1974)
Coimbatore	485	162	647	733	Paulsamy a Lakshmanachary (1986)
Garhwal	256	150	406	559	Agarwal & Goyal (1987)
Cherrapunji	579	990	1,569	10,373	Ramakrishnam & Ram (1988)
Madurai	984	2,897	3,881	575	Karunaichamy & Paliwal (1989)
Rundranath	492	328	820	1,586	Ram *et al.*, (1989)
Gopeshwar	1,184	706	1,890	1,787	Sah & Ram (1989)
Kahkesam	1,212	244	1,456	1,496	Karunaichamy & Paliwal (1994),
Kundha	4,857	527	5,384	2,900	Senthilkumar *et al.* (1998)
Varanasi	4,560	-	-	-	Singh (1972)
Grass Hills	4,561	722	5,283	3,184	Present study

[1] Aboveground net primary production, [2] Belowground net primary production and [3] Total net primary production.

iting factor (Paulsamy 1992). The BNP of Grass Hills is high at 772 $g \cdot m^{-2} \cdot yr^{-1}$ (Table 3) which is comparable with the data obtained in humid grassland of Gopeshwar (Sah and Ram 1989). This may be attributed to the translocation of primary materials from the luxurient aboveground production as observed by Karunaichamy and Paliwal (1989) in the humid grassland of Kanyakumari, Western Ghats, India. The annual litter production of Grass Hills ecosystem was 730 g/m^2 (Table 3), and it generally follow the changes in the standing dead compartment (Singh and Joshi 1979).

The turnover rate and time for aboveground parts of the community were observed to be 1.672 $g \cdot m^{-2} \cdot yr^{-1}$ and 0.598 years, respectively, and for belowground parts they were 0.486 $g \cdot m^{-2} \cdot yr^{-1}$ and 2.055 years. The turnover rate seems to be rapid and comparable with that of a humid grasslands of Kanyakumari district, Western Ghats (Karunaichamy and Paliwal 1994). This is in tune with the generalization that humid grasses have higher turnover rates than those in semi-arid regions (Coupland 1979). About 49% of belowground biomass was replaced each year. Singh and Krishnamurthy (1981) pointed out that this phenomenon in humid grasslands is the result of higher rate of root material decomposition than the amount of root growth.

Table 3 gives the annual balance sheet of dry matter at Grass Hills ecosystem. It indicates that the dead shoots contributed annually 1,494 g/m^2 (32%) to the aboveground net production of 4,561.08 g/m^2. The belowground and litter disappearances were 730 and 204 $g \cdot m^{-2} \cdot yr^{-1}$ respectively. System transfer function (STF) is the factor by which the system block multiplies the input to generate the output (Golley 1965) and reflects the orientation

Table 3. Annual balance sheet of dry matter in a humid annual fire influencing grassland of Grass Hills, Western Ghats

Component	g/m^2
Aboveground parts	
Initial biomass	1,448.08
Above ground net production	4,561.08
Transfer to dead production	1,493.76
Biomass at the end	1,595.58
Dead shoots	
Initial biomass	232.38
Net production	1,493.76
Transfer to litter	730.00
Biomass at the end	453.56
Litter	
Initial biomass	79.12
Net production	730.00
Disappearance	204.40
Biomass at the end	605.40
Belowground parts	
Initial biomass	985.82
Net production	722.24
Disappearance	730.00
Biomass at the end	1,009.94

Table 4. System trsansfer functions of a humid annual fire influencing grassland of Grass Hills, Western Ghats

Compartments		
From (input)	To (output)	System transfer functions (STF)
TNP	ANP	0.86
TNP	BNP	0.14
ANP	L	0.16
L	LD	0.28
TNP	TD	0.18
SD	L	0.48
ANP	SD	0.32
TNP	L	0.14

TNP = Total net production
ANP = Aboveground net production
BNP = Belowground net production
L = Litter
SD = Standing dead
LD = Litter disappearance
TD = Total disappearance

of the functioning of an ecosystem in space and time (Sims and Singh 1971). The net accumulation and disappearance of dry matter in Grass Hills ecosystem are shown in and the system transfer function are exhibited in Table 4. Of the total input of 14.47 $g \cdot m^{-2} \cdot d^{-1}$ into the system, about 86 and 14% were allocated to live shoots and belowground parts, respectively. Of the total disappesarance of 17.68%, 13.8% was channelled to belowground parts and 3.8% was to litter. As a consequence, There was a net accumulation of 82.32% dry matter in the system.

Singh and Joshi (1979) pointed out that in humid grasslands it is because of this surplus production that grazing or burning becomes important for the maintenance of these communities at a given level of succession, otherwise they would progress towards the new higher successional stage. Similar trend of results was already observed (Karunaichamy and Paliwal 1994, Meenakshisundaravalli and Paliwal 1997). Hence it is known that annual summer fire in Grass Hills ecosystem highly enhances the net primary production and maintains the community at the seral stage of *C. zeylanicus* dominated condition. We suggest that the Grass Hills, a part of Indira Gandhi Wild Life Sanctuary, can be managed effectively at useful *C. zeylanicus* dominated condition by judicial application of prescribed burning.

LITERATURE CITED

Agarwal, A.K and A.K. Goyal. 1987. Effect of grazing on net primary production and system transfer function in a Western Himalayan grassland community. Tropical Grasslands 21:154-158.

Billore, S.K. and L.P. Mall. 1977. Dry matter structure and its dynamics in *Sehima* grassland community. II. Dry matter dynamics. Tropical Ecology 19:29-35.

Britton, C.M., H.A. Wright, B.E. Dhal and D.N. Ueckert. 1987. Management of tobosa grass rangeland with prescribed fire. Management Note 12, Contribution NO. T-9-481, College of Agricultural Sciences, Texas Tech. University, pp. 1-5.

Chinnamani, S. 1981. Grasslands of south India and its ecology, floristic composition and utility. Bulletin of Botanical Survey of India 23:129-134.

Choudhary, V.B. 1972. Seasonal variation in standing crop and net aboveground production in *Dichanthium annulatum* grassland at Vqranasi. *In* P.M. Golley and F.B. Golley (eds.) Tropical ecology with an emphasis on organic production. Univ. of Georgia, Athens, USA. pp.51-57.

Coupland, R.T. 1979. Grassland ecosystem of the world: analysia of grasslands and their uses. Cambridge University Press, Cambridge.

Dahlmann, R.G and C.L. Kucera. 1965. Root productivity and turnover in native prairie. Ecology 46:84-89.

Golley, F.B. 1965. Structure and function of an old-field broomsedge community. Ecological Monographs 35:113-131.

Greig - Smith, P. 1964. Quantitative pant ecology (2nd ed.) Butterworths, London.

Gupta, J.N. 1987. Ecophysiological association and balance among some grassland communities of Jhansi, India.

Journal of Agronomy and Crop Science 159:293-298.

Karunaichamy, K.S.T.K. and K. Paliwal. 1989. Primary productivity and transfer dynamics of grazinglands at Madurai, Southern India. Tropical Ecology 30:111-117.

Karunaichamy, K.S.T.K. and K. Paliwal. 1994. Dry matter production and transfer dynamics in a humid grassland of Western Ghats in Southern India. Tropical Grasslands 28:17-23.

Meenakshisundaravalli, V. and K. Paliwal. 1997. Dry matter production and nitrogen dynaimcs in the semi-arid grazingland of Madurai, India. Tropical Ecology 38:81-86

Milner, C. and P.R. Hughes. 1968. Methods for the measurement of the primary productivity of grassland. IBP Handbook No.6. Blackwall Scientific Publication, Oxford.

Paulsamy, S. 1992. Role of fire in the maintenance of *Chrysopogon zeylanicus* Thw. dominated grasslands of Grass Hills, Western Ghats, India. Ph.D. Thesis, Bharathiar University, Coimbatore, India.

Paulsamy, S., S. Manian, K. Udaiyan, K. Arumugasamy, and T.N. Rangarajan. 1997. Effect of annual summer fire on primary production in Grass Hills ecosystem, Western Ghats. Geobios 24:151-154.

Paulsamy, S., S. Manian, K. Udaiyan, T.N. Rangarajan and K. Arumugasamy. 1996. Short term studies on the ecological status of weeds in an annual fire influenced *Chrysopogon zeylanicus* dominated grassland, Western Ghats. The World - Weed 3:67-75.

Paulsamy, S., T.N. Rangarajan, S. Manian, and K. Udaiyan. 1995. Impact of annual summer fire on the sociological attributes of the fern, *Pteridium aquilinum* L. in the Grass Hills ecosystem, Western Ghats, India. Journal of Economic and Taxonomic Botany 19:745-749.

Sah, V.K. and J. Ram. 1989. Biomass dynamics, species diversity and net primary production in central Himalayan high altitude grassland. Journal of Ecology 77:456-468.

Scifres, D.J. 1980. Brush Managment : Principles and practices for Texas and Southwest. Texas A and M Univ. Press, College Station.

Senthilkumar, K., S. Manian, K. Udaiyan and S. Paulsamy. 1998. Elevated biomass production in burned natural grasslands in southern India. Tropical Grasslands 32:50-63.

Sims, P.L. and J.S. Singh. 1971. Herbage dynamics and net primary production in certain ungrazed and graszed grasslands in North America. *In* French, N.R. (ed.), Preliminary analysis of structure and function in grasslands. Colorado State University, Fort Collins.pp. 51-124.

Singh, A. K. 1972. Structure and uet primary production and mineral contents of two grassland communities of Chakia hills, Varanasi. Ph.D. Thesis, Banaras Hindu University, Varanasi, India.

Singh, P. 1987. Rangeland reconstruction and management for optimizing biomass production. National Rangeland Sympoium, Jhansi, India. PP. 9-12.

Singh, J.S. and M.C. Joshi. 1979. Primary production *In* Coupland, R.T. (ed.) Grassland ecosystem of the world : Analysis of Grasslands and their uses. Cambridge University Press, Cambridge. pp. 197-218.

Singh, J.S. and L. Krishnamurthy. 1981. Analysis of structure and function of tropical grassland vegetation of India. Indian Review of Life Science 1:225-270.

Singh, J.S. and P.S. Yadava. 1974. Seasonal variation in composition, plant biomass and productivity of a tropical grassland at Kurukshetra, India. Ecological Monographs 44:351-376.

Trivedi, B.K. and G.P. Mishra. 1979. Seasonal variations in species compositions, plant biomass and net community productivity of two grasslands on *Sehima* - *Dichanthium* cover type. Tropical Ecology 20:114-125.

Trlica, M.J. and J.S. Singh. 1979. Creation, translocation and utilization of reserves.. *In* Perry, R.A. and D.W. Goodall (eds.). Aridland ecosystems. Cambridge Univ. Press, London. pp. 537-571.

Wilson, J. 1964. Working plan for the Coimbatore South Division. Proc. Chief Conservator of Forests, Madras, India. Proc. Mis. No. 186. p. 317.

Wright, H.A. 1985. Effects of fire on grasses and forbs in sagebrush grass communities. *In* Sanders, K. and J. Durham (eds.). Rangeland fire effects. Idaho State Office, USDI-Bureau of Land Management, Boise Idaho. pp.12-21.

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