Madras Agric. J. 89 (7-9) : 491-498 July-September 2002

https://doi.org/10.29321/MAJ.10.A00256

Strategy to enhance herbage yield in temperate pasture grasslands of Nilgiris

C.M. GANESAN, S. ARVINTH AND S. PAULSAMY
Dept. of Botany, Kongunadu Arts and Science College, Coimbtore-641 029, Tamil Nadu.

Abstract : The herbage yield in the form of aboveground net primary production is getting paramount importance for herbivores and hence ecosystem management. To compare the herbage yield (aboveground net primary production) and to determine the influence of certain environmental factors, six grassland communities (community near Kongunadu Arts and Science College - Site I; community near Bharathiar University - Site II; community at Burliar - Site III; community at Coonoor Site - IV; community at Ooty - site V; community at Nadugani - Site VI) located at different climatic zones (Sites I and II tropical; Sites III and VI subtropical and Sites IV and V temperate) were selected. The study revealed that the tropical sites registered higher annual net primary production along with higher energy potential in biomass and it is followed by subtropical and temperate sites. When all the sites are considered together, the physical factor, temperature and the intrinsic factor, higher proportion of C_4 plants were directly correlated with aboveground net primary production. Contrary to this, the factors *viz.* the rainfall and the proportion of C_3 plants have inverse relationship with aboveground net production. Since there was no limiting physical factors in the studied temperate sites (Sites IV and V), the population of C_3 plants alone largely determines the community production. Hence, planting tree species randomly in the studied temperate sites, where the C_3 plants are more, can enhance the primary production owing to their higher efficiency of production in shade condition.

Key words : Herbage yields, Environmental factors, Photosynthetic pathway, Grasslands.

Introduction

The herbage yield in the form of aboveground primary production in grasslands is the major pasture for herbivores. The biomass production of aboveground plant parts in any ecosystem is mainly governed by physical factors, soil nature, type of species, photosynthetic pathway and efficiency of fixation radiant energy by primary producers etc. If the structural modifications are correctly practiced in communities so as to utilize the resources effectively, the primary production will increase. The present study, mainly aimed to know the role of certain intrinsic and extrinsic factors on aboveground primary production, was carried out at six different grasslands.

Study Areas

For the present study, six grassland communities located under three different macroclimatic conditions were selected. The sites I and II respectively near Kongunadu Arts and Science College and Bharathiar University, Coimbatore are lying under tropical climate with an altitude of ca.420 m above MSL. The sites III (ca. 900 m above MSL) and VI (ca. 950 m above MSL) are situated in subtropical climate respectively at Burliar and Nadugani of Nilgiri district. The remaining two sites, IV and V are located under temperate climate in Coonoor (ca. 1600 m above MSL) and Ooty (ca. 2240 m above MSL) respectively. The climatic factors of the study areas during the study period of one year (year 2000-2001) is given in Table 1. The temperature was always higher in tropical sites (Sites I and II) and it was followed by sutropical (Sites III and VI) and temperate sites (Sites IV and V). Higher rainfall was recorded in temperate sites followed by subtropical and tropical sites. The relative humidity also varied widely across the sites.

In all the study sites, grasses are the dominant form and they are in association with considerable number of forbs also. The floristic list of the study sites with C_3 and C_4 plant composition is shown in Table 2.

Materials and Methods

An one hectare sampling plot was selected in each site for the present study. The flora of the sampling area was categorised into C_3 and C_4 plants based on the photosynthetic pathway by employing the iodine test in leaves (Bolhar - Nordenkampf, 1982). The changes in the density

Table 1. Floristic list and C_3 and C_4 plant compostion in the study sites

S.No	Name of the species	Study sites					
		Site I	Site II	Site III	Site IV	Site V	Site VI
	Grasses						
1	*Cymbopogan caesius***	-	+	-	-	+	-
2	*Heteropogon controtus***	-	+	-	-	+	-
3	*Setaria intermedia**	+	+	-	-	-	-
4	*Panicum indiarm**	+	+	-	-	-	+
5	*Cenchrus ciliaris***	+	+	+	+	-	-
6	*Chloris barbata* **	+	+	+	+	+	+
7	*Themeda triandra***	-	+	+	-	-	+
9	*Brachiaria remosa***	+	+	+	+	-	+
10	*Bothriochloa pertusa***	+	+	-	-	-	-
11	*Eragrotis plumosa***	+	+	+	+	-	-
12	*Eragrotis unioloides***	-	-	+	-	-	-
13	*Chloris polstachya***	-	-	+	+	-	-
14	*Cymbopogon citratus***	-	-	+	+	-	+
15	*Urochola panicoides**	-	-	-	-	+	-
16	*Eragrostis stenophylla**	-	-	-	-	+	+
17	*Briza maxima**	-	-	-	-	+	-
18	*Briza minor**	-	-	-	-	+	-
19	*Chrysopogon verticillatus***	-	-	-	-	+	-
20	*Cenchrus granulaxis***	-	-	-	-	+	-
21	*Chrysopogon asperi***	-	-	-	-	+	+
22	*Pennisetum purpuriem***	-	-	-	-	+	+
23	*Cymbopogon colartus***	-	-	-	-	-	+
24	*Apluda mutica**	-	-	-	-	-	+
25	*Dactyloctenium agyptium**	-	-	-	-	-	+
	Total	8	11	9	7	12	13
	Sedges						
26	*Cyperus rotundus***	+	+	+	+	+	+
27	*Cyperus angulatus**	+	+	-	-	-	+
28	*Cyperus articulatus**	-	-	+	-	-	+
29	*Kyllinga bulbosa**	-	-	+	-	-	+
30	*Kyllinga triceps**	-	-	-	+	+	+
31	*Cyperus compressus**	-	-	-	+	-	-
32	*Cyperus nilagiricus**	-	-	-	-	+	-
33	*Kyllinga cypermia**	-	-	-	-	+	-
	Total	2	2	3	3	4	5
	Forbs						
34	*Lantana camara**	+	+	+	+	+	+
35	*Tinospora cardifolia**	+	+	+	+	+	+
36	*Commelina benghalensis**	+	+	+	+	+	+
37	*Achyranthus aspera**	+	+	+	+	+	+
38	*Croton sparsiflorus**	+	+	+	-	+	+
39	*Boerhaavia repens**	+	+	+	+	+	+
40	*Fluggea leucophyrus***	-	+	+	-	+	+
41	*Boerhaavia diffusa**	+	+	+	+	+	+

Table 1. (Contd...)

S.No	Name of the species	Study sites					
		Site I	Site II	Site III	Site IV	Site V	Site VI
42	*Boerhaavia verticillata**	-	+	+	+	+	+
43	*Dodonaea viscosa**	-	+	+	+	+	+
44	*Hybiscus esculentus**	-	+	+	+	+	+
45	*Tephrosia procumbens**	+	+	+	+	+	+
46	*Kedrostis restrata**	-	+	+	+	+	+
47	*Blepaharis boerhaaviaefolia**	-	+	-	+	+	+
48	*Ipomea obscura**	+	+	-	+	+	+
49	*Justicia betonica**	-	+	+	-	+	+
50	*Mirabilis jalapa**	-	+	-	+	-	-
51	*Tynospora cardifolia***	+	+	+	-	-	-
52	*Stachytarpheta indica***	+	+	+	+	+	-
53	*Crossandra undulaefolia***	-	+	-	-	+	-
54	*Crotalaria juncea***	+	+	+	+	+	-
55	*Clitoria ternata***	+	+	+	+	+	-
56	*Lactuca runcinata***	-	+	-	+	-	-
57	*Peritrophe bicalyculata***	+	+	-	+	-	-
58	*Syndrella nodiflora***	-	+	-	-	-	-
59	*Ruellia patula***	-	+	-	-	-	-
60	*Asystasia gangtica***	-	+	-	-	-	-
61	*Cissus hayneana***	-	+	-	-	+	+
62	*Malva verticillata***	+	+	+	-	+	-
63	*Corchorus acutandulus***	+	+	+	+	+	-
64	*Tridax procumbens***	+	+	+	+	+	+
65	*Coccinia indica***	+	+	+	+	+	-
66	*Euphorbia hirta***	+	+	+	+	+	+
67	*Euphorbia heterophylla***	+	+	+	+	+	-
68	*Amarantus tristis***	+	+	+	+	+	+
69	*Aerva lanata***	-	+	+	+	+	-
70	*Eclipta alba***	-	-	+	+	+	+
71	*Cardiosperm halicacabum**	+	+	+	+	+	-
72	*Andrephogus paniculata***	+	+	+	+	+	+
73	*Caspicum annum***	-	+	+	+	+	-
74	*Parthenium hysterophorus***	+	+	+	+	+	+
75	*Vernonia monosis**	+	+	+	+	+	-
76	*Lagasca mollis***	+	+	+	+	+	-
77	*Alsicarpus rugosus***	+	-	+	-	+	-
78	*Borreria hispida***	+	-	+	-	-	-
79	*Borreria olymoldes***	+	-	+	-	-	-
80	*Indigofera tinctoria***	+	-	+	-	+	-
81	*Paspalidium flavidum***	+	-	+	-	+	+
82	*Rhyncosia minima***	+	-	+	-	+	-
83	*Oldenlandia umbellata***	+	-	+	-	+	+
84	*Digera arvensis**	+	-	+	+	+	-
85	*Ocimum canum***	+	-	-	-	+	+
86	*Malvastrum coromandeliana***	+	-	-	+	+	-
87	*Evolvulus alainoides**	+	-	-	-	+	+
88	*Vernonia cinerea**	+	-	+	+	+	-

Table 1. (Contd...)

S.No	Name of the species	Study sites					
		Site I	Site II	Site III	Site IV	Site V	Site VI
89	*Convolvulus murgiantous**	+	-	-	-	-	-
90	*Ariscarpus moniferii**	-	-	+	+	+	-
91	*Sida acuta**	+	-	+	+	+	-
92	*Crotalaria prostrata**	+	-	+	+	+	-
93	*Oxalis corniculala**	-	-	+	+	+	+
94	*Acacia indica***	-	-	+	+	+	-
95	*Ipomea headerifolia**	-	+	+	+	+	+
96	*Salvia oficinalis**	-	-	+	+	+	-
97	*Cassia absus**	-	-	+	+	+	-
98	*Orthosiphon glabratus**	-	-	+	+	+	-
99	*Tophrosia purpurea**	+	-	+	+	+	-
100	*Leucus bifora**	-	-	+	+	+	-
101	*Leucus aspera**	+	+	+	+	+	+
102	*Ligustrum robustrum bedome**	-	-	+	-	+	+
103	*Portulaca qudrifida**	+	-	+	+	+	+
104	*Strobilanthes gracifis**	+	-	+	+	+	+
105	*Ageratum conyzoides***	-	-	+	+	+	+
106	*Desmodium triquetrum***	-	-	+	+	+	+
107	*Eupatorium bignoniaum**	-	+	+	+	+	+
108	*Hibiscus furcatus**	-	+	+	+	+	+
109	*Datura mentel**	-	-	+	+	+	-
110	*Centella asiatica**	-	+	+	+	+	+
111	*Solanum nigrum**	-	+	+	+	+	-
112	*Mimosa pudica**	+	+	+	+	+	+
113	*Jasminum auriculatum***	+	-	+	+	+	-
114	*Sida rhombifolia**	+	-	+	+	+	+
115	*Polygonum hydropiper**	+	-	+	-	+	-
116	*Convolvulus filifolius**	+	+	+	+	+	+
117	*Crotalaria retusa**	+	+	-	+	+	-
118	*Acacia concinna***	+	-	-	+	+	+
119	*Ipomea alba**	+	+	-	+	+	-
120	*Cassia italica***	+	+	-	+	+	+
121	*Leucus chinesis**	+	-	-	+	+	-
122	*Ligustrum perrotteii**	+	-	-	+	+	+
123	*Polygala bulbothrix**	+	-	-	+	+	-
124	*Strobilanthes micrantha**	+	+	-	+	+	+
125	*Hibiscus vitifolius**	+	-	-	+	+	-
126	*Polygonum donilmeisner***	-	-	-	-	+	+
127	*Lactuca hastata***	-	-	-	-	+	-
128	*Acacia melanoxylon***	-	-	-	-	+	+
129	*Euphorbia glandulosum***	-	-	-	-	+	-
130	*Helichrysum wightii***	-	-	-	-	+	+
131	*Spergula arvensis***	-	-	-	-	+	-
132	*Hibiscus lampus**	-	-	-	-	+	+
133	*Cardiosperm luridan**	-	-	-	-	+	-
134	*Abutilon indicum***	+	+	+	-	+	+

Table 1. (Contd...)

S.No	Name of the species	Study sites					
		Site I	Site II	Site III	Site IV	Site V	Site VI
135	*Cissus quadrangularis**	+	+	+	-	+	-
136	*Emilia sonchifolia***	-	-	+	-	+	+
137	*Curcurma neilgherrensis**	-	-	-	-	-	+
138	*Justicia simplex***	+	-	+	+	-	+
139	*Leea indica**	-	-	-	-	-	+
140	*Osbeckia leschenanltiana**	-	-	-	-	-	+
141	*Smilax perfoliata**	-	-	-	-	-	+
142	*Smilax zeylanica**	-	-	-	-	-	+
143	*Polypodium barbatum**	-	-	-	-	-	+
144	*Osbeskia vitifolius**	-	-	-	-	-	+
145	*Ricinus communis***	-	-	-	-	-	+
	Total	61	56	73	71	93	60
	Grand total	71 (C3-36; C4-35)	69 (C3-33; C4-36)	85 (C3-43; C4-42)	81 (C3-48; C4-33)	109 (C3-60; C4-49)	78 (C3-45; C4-33)

* - C_3 plants ** - C_4 plants

Table 2. The density (individuals /m^2) and percentage contribution of C_3 and C_4 plant species to the total community in the study sites

Year and month	Study sites											
	Site I		Site II		Site III		Site IV		Site V		Site VI	
	C_3	C_4	C_3	C_4	C_3	C_4	C_3	C_4	C_3	C_4	C_3	C_4
2000												
Dec	757	1099	880	1858	648	561	822	678	1832	1927	712	698
2001												
Jan	523	856	807	1757	672	571	878	859	1639	1798	742	721
Feb	439	831	760	1540	749	536	810	753	1610	1349	882	847
Mar	467	484	827	1572	651	511	836	627	1692	1759	690	561
Apr	421	447	579	1424	628	489	621	425	1288	1232	648	778
May	381	436	845	1550	596	463	648	480	1623	1516	611	559
Jun	738	1376	1096	1953	744	568	837	694	2155	2142	923	695
Jul	678	1452	1075	1775	874	654	945	707	2398	2347	998	742
Aug	647	958	1021	1857	920	738	869	722	2543	2567	1070	730
Sep	743	1067	1133	2192	1062	779	854	655	2356	1008	1195	810
Oct	761	1051	956	1801	1142	805	906	708	2705	3161	1244	866
Nov	815	1099	817	1499	1146	775	865	603	1515	1988	1244	961
Total	7370	11156	10796	20778	9832	7450	9891	7911	23356	22794	10959	8968
Mean	614.17	929.67	899.67	1731.50	819.33	620.83	824.25	659.25	1946.33	1899.50	913.25	747.33
Percentage	39.75	60.18	32.48	67.52	56.89	43.11	55.56	44.44	50.60	49.39	55.00	45.00

of C_3 and C_4 plants at monthly intervals during the study period of one year was estimated by following the method of Curtis (1959) through laying twenty quadrats (1x1 m each) randomly in each site at every sampling time.

The aboveground plant biomass was estimated by the harvest method (Milner and Hughes, 1968). The optimum quadrat size (1 x1 m) was obtained by the species-area curve method (Goodall, 1952) and 10 quadrats were sampled randomly at monthly intervals for the study period of one year from December, 2000 to November, 2001. Harvested samples were separated into C_3 and C_4 plant compartments by identifying the species. The sorted out plant compartments were weighed after oven drying at 80°C for 2 days. The aboveground net primary production was calculated by the sum of positive changes in aboveground biomass plants plus mortality (Singh and Yadava, 1974). Five replicates were maintained for biomass studies.

The accumulated energy in terms of calories in the aboveground biomass was estimated at monthly intervals for the study period in ten samples at each site according to the method followed by Jana and Pal (1981). The correlation existing between net primary production and certain variables such as, maximum and minimum temperatures, rainfall, energy potential and per cent densities of C_3 and C_4 plant species were also obtained.

Results and Discussion

The species composition was widely varied across the sites (Table 2). Grasses, sedges and forbs were the major constituent groups in all the study areas. Their site-wise contribution to the total community is as follows: site I - 8 grasses, 2 sedges and 61 forbs; site II - 11 grasses, 2 sedges and 56 forbs; Site III - 9 grasses, 3 sedges and 73 forbs; Site IV - 7 grasses, 3 sedges and 71 forbs; Site V - 12 grasses, 4 sedges and 93 forbs and Site VI - 13 grasses, 5 sedges and 60 forbs. The richness of the grasses was lower in comparison to forbs. However, the contribution of individuals to the total community by the grasses was generally higher in all sites. This is explained that the presence of wide ecological amplitude by having adaptability and suitability to various ecological niches in graminae members could be the possible reason for their higher density and better establishment (Shantz, 1954; Misra, 1980; Manorama, 1996).

The density of the C_3 an C_4 plant species varied considerably between the study sites (Table 2). The population size and percentage contribution of C_4 plants was generally greater in tropical sites and they were decreased progressively in subtropical and then in temperate sites. The reverse was true in the case of C_3 plants. Furbank (1998) pointed out that the C_4 plants are particularly successful in environment, where temperature and light intensity are high. Saxena and Ramakrishnan (1984) stated that the C_3 plants perpetuate well usually in the regions with less solar radiation and temperature.

The monthly changes in the aboveground biomass of all the study sites showed much variation. In tropical sites (Sites I and II) the minimum and maximum biomass were 250 and 1990 g m^{-2} respectively. In subtropical sites (Sites III and VI) the range of aboveground biomass was between 450 and 1900 g m^{-2} and in temperate sites (Sites IV and V) it was between 300 and 1900 g m^{-2}. Generally, the aboveground community biomass in all the six study sites were higher during the rainy season. Singh and Krishnamurthy (1981) reported that the enhancement of biomass during rainy season is the characteristic feature of monsoonal grasslands.

The annual net aboveground production of the study sites is presented in Table 3. The tropical sites registered higher net primary production (1250 gm^{-2} in Site I and 1355 g m^{-2} in Site II) over those of temperate sites (600 g m^{-2} in Site IV 625 g m^{-1} in Site V). The subtropical (Sites II and VI) occupied intermediate position between tropical and temperate sites in terms of community production. The community production observed in present tropical study sites are comparable to that of Jhansi tropical grasslands (Singh and Krishnamurthy, 1981). Simmilarly, the estimated aboveground production in the study sites of temperate climate also falls within the reported range for other temperate grasslands (Whittaker, 1970).

The content of energy accumulated in the aboveground biomass on annual basis is given in Table 4. The tropical study sites recorded higher energy in biomass than the other sites. This may be attributed to the higher population

Table 3. Annual aboveground net primary production (g m^{-2}) and energy content in the aboveground biomass of the study sites

Attributes	Study sites					
	Site 1	Site II	Site III	Site IV	Site V	Site VI
Annual aboveground net primary productuion (g m^{-2})	1250	1355	940	600	625	983
Energy content * (cal/mg)	16.1	14.7	14.5	14.5	14.3	14.1

* Annual mean value

Table 4. Correlation coefficient (r) between net community primary production and certain environ mental variables in the study sites

Environmental variables	Correlation coefficient (r)
Maximum temperature (°C)	0.983*
Minimum temperature (°C)	0.659*
Rainfall (mm)	-0.883**
Relative humidity (%)	-0.859**
C_3 plants (mean percentage)	-0.781**
C_3 plants (mean percentage)	0.780**
Energy content (cal mg^{-1})	0.537*

* P< 5%; ** < 1%

of C_4 plants in tropical sites and they could do effective photosynthesis under high temperature and high light intensity (Fitter and Hay, 1987). The less energy content accounted in the aboveground biomass of temperate sites may be due to the higher density of C_3 plants which do poor photosynthesis under open sun and high temperature (Ehleringer and Brokman, 1977).

The functional relationship between aboveground community production and certain variables is given in Table 4. It exhibits that the factors such as maximum and minimum temperatures, proportion of C_4 plants and content of energy accumulated in the biomass have positive relationship with aboveground net primary production. The linear relationship between temperature and community production was already noted (Barbour *et al.* 1980). The increased primary production in the communities of higher proportion of C_4 plants is an interesting feature in this study. Furbank and Taylor (1995) stated that under high temperature and high intensity, the C_4 plants have a CO_2 concentrating mechanism which reduces the rate of photorespiration and increases the rate of carbon assimilation. Callaghan *et al.* (1985) reported that the accumulation of energy in the living biomass at most circumstances increased the production function.

The other variables such as annual rainfall, relative humidity and the higher proportion of C_3 plants have negative correlation with aboveground community production. Barbour *et al.* (1980) found that at high levels of precipitation, more water is lost as runoff, or drains below the root zone where it no longer influences production. Further more, he reported that the relationship between productivity and annual rainfall is nearly linear only at values below 500 mm. Singh and Joshi (1979) explained that the increased dryness of air indicated by higher relative humidity naturally reduces the primary production in grassland communities. The higher proportion of C_3 plants in open sun at sites IV and V do less effective photosynthesis which results lower community production. Callaghan *et al.* (1985) pointed out that shade condition takes primary role in enhancing the rate of carbon assimilation and hence the primary production in C_3 plants.

The aboveground biomass production in the studied temperate sites (Sites IV and V) of Nilgiris is an important source of food for the herbivores and hence to maintain the ecosystem balance. The study revealed that to promote the production in temperate sites, casting shade upon the grasses is essential. This is possible only by some structural modifications in grassland communities. Hence a suitable technique (i.e.) planting tree species adequately may be recommended for effective harvesting of solar energy through biomass. However, the productivity responses along environmental gradients are complex and non linear. Hence, it will be necessary to accumulate more data on these relationships before the interaction of climate, life-form and productivity are understood and are able to be predicted.

References

Barbour, J.R., Sage, R.W., Flanagan, B. and Percacy, R.W. (1980). Climate and the evolution of C_4 photosynthesis. *Tree* **6:** 95-97.

Bolhar - Nordenkampf, H.R. (1982). Shoot morphology and leaf anatomy. In : *Techniques in Bioproductivity and photosynthesis*. Coombs, J. and D.O. Hall (eds.), Pergemon Press, Oxford, New York, Sydney, Paris.

Callaghan, T.V., Lawson, G.J., Millar, A. and Scott, R. (1985). Environmental aspects of agroforestry. *In : Agroforestry*. A discussion of R & D requirements MAFF 1985, HMSO, 50-76.

Curtis, J.T. (1959). The vegetation of Wisconsin: An ordination of plant communities. University of Wisconsin Press, Wisconsin.

Ehleringer, J.R. and Brokman, O. (1997). Quantum yields for CO_2 uptake in C_3 and C_4 plants: Dependence on temperature, CO_2 and O_2 concentration. *Plant Physiology* **59:** 86-92.

Furbank, R.T. (1998). C_4 pathway. In: *Photosynthesis*. Ragavendra A.S. (ed.), Cambridge University Press, London.

Furbank, R.T. and Taylor, W.C. (1995). Regulation of photosynthesis in C_3 and C_4 plants: A molecular approach. *The plant Cell* **7:** 797-807.

Fitter, A.H. and Hay, R.K.M. (1987). Environmental Physiology of Plants. Academic Press, London, New York, Tokyo, Toronto.

Goodall, D.W. (1952). Quantitative aspects of plant distribution. *Biological Rev.* **27:** 194-245.

Jana, B.B. and Pal, G.P. (1981). Energy contents of common fish food organisms. *Biol. Bull. India.* **3:** 93-100.

Monorama, S. (1996). Studies on the natural regeneration of lime mined sites at Madukarai, Coimbaotre District, Tamil nadu, India. Ph.D., Thesis, Bharathiar University, Coimbaotre, India.

Milner, C. and Hughes, P.R. (1968). Methods for the measurement of the primary productivity of Grassland. IBP Hand book No.6. Black well scientific publication, Oxford.

Mishra, G. (1980). Growth characters of certain grasses in response to clipping and moisture strees. Ph.D.Thesis, Banaras Hindu University, India.

Saxena, K.S. and Ramakrishnan, P.S. (1984). C_3/C_4 species distribution among successional herbs following slash and burn agriculture (jum) in north-eastern India. *Acta oecologica / Oecologica Plantarum* **5:** 335-346.

Shantz, H.L. (1954). The place of grassland in the earth's cover of vegetation. *Ecology* **35:** 143-145.

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

Singh, J.S. and Joshi, M.C. (1979). Primary production, *In: Grassland ecosystems of the world*. pp. 197-218. CUP, Cambridge.

Singh, J.S. and Krishnamurthy, L. (1981). Analysis of structure and function of tropical grassland vegetation of India. *Rev. Life Sci.* **1:** 225-270.

Whittaker, R.H. (1970). Communities and Ecosystem. MaCmillan & Co., New York.

(Received : February 2002 ; Revised : May 2002)