higher biomass of autotrophs can be explained when one would assume the utilization of these elements for growth and reproduction by the phytoplankton community. The assumption is further evidenced by the lack of precipitation of phosphates which require higher pH, whereas beel water always remained in an acidic to near neutral range. The correlation between the phosphates and phytoplankton revealed a negative relationship ($r = -0.5960$) whereas with total plankton it was $r = -0.5225$, both of moderate degree, indicating its link in the life cycle of autotrophs (figure 2).

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PRODUCTIVITY AND BIOMASS TURNOVER RATES FOR SERAL GRASSLANDS OF CHERRAPUNJI IN NORTHEASTERN INDIA

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In tropical grasslands, where net primary productivity and litter decomposition rates are higher compared to those in their temperate counterparts, dry matter is recycled faster. Further, in the tropics, vegetation is the chief storage compartment of nutrient elements. Consequently, exchanges between compartments are faster. Turnover rate is a useful measure for comparing the exchange rates between different compartments[1]. Much work on these aspects of temperate grasslands has been carried out[2–5]. However, information for tropical grasslands is limited[6,7].

The secondary successional grasslands (representing an arrested stage during plant succession) at Cherrapunji (25° 15′ N, 91° 45′ E; 1300 m altitude), one of the wettest spots of the world (annual average rainfall of 1040 cm, could be as high as 2460 cm in an exceptional year such as 1974), are derived from the climax evergreen rain forests[8,9]. These grasslands are under stress because they occur under excessive rainfall conditions on highly leached nutrient-deficient soils on limestone formations with karst topography characterized by extensive underground tunnels. They are also subjected to frequent perturbations due to fire. This paper considers turnover rates for the biomass of grasslands that developed under these stress conditions.

Four grassland types were selected: (i) The *Osbeckia* type developed on a well-developed soil (with an average depth of 40 cm) and with dominant species such as *Osbeckia crinta*, *Arundinella bengalensis*, *Chrysopogon gryllus* and *Fimbristylis thomsonii*; this grassland was burnt six years prior to the initiation of this study. (ii) The *Arundinella* type which was similar to the *Osbeckia* type but had an additional burning, one month prior to the initiation of this study; the dominant species are *Arundinella bengalensis*, *Chrysopogon gryllus*, *Carex cruciata* and *Eulalia trispicata*. (iii) The *Ischaemum* type developed on a site subjected to burning at 2-year intervals and with species such as *Ischaemum goeb'i* and *Fimbristylis complanata* as the dominant ones. (iv) The *Eragrostiella* type developed on ill-weathered shallow (average depth of 30 cm) and nutrient-deficient soils with species such as *Eragrostiella leoptera*, *Borreria articularis* and *Fimbristylis complanata* as dominant components.

Above-ground and below-ground biomass measurements were carried out at monthly intervals, based on 10 harvests from 1 m^2 quadrats, at each replicate site. Above-ground biomass was divided into living, standing dead and litter. Below-ground biomass was harvested by excavating 30-cm-deep blocks of soil (10 replicates at each site) using a 10-cm-diameter soil core. The soil block was divided into three units at 10 cm intervals (0–10, 10–20 and 20–30 cm) for measuring root distribution. Both above-ground and below-ground parts were washed and rinsed with distilled water, dried at 80°C for 24 h, and weighed. Above-ground net primary productivity was calculated by including dead material disappearing during monthly intervals, following the method of Weigert and Evans[10]. Below-ground net primary production was estimated by summation of positive increments of root biomass alone[3]. The biomass and productivity measurements are based on data over a 2-year period, 1983–85.

Turnover of biomass was calculated using the formula

$$\text{Turnover rate} = \frac{\text{ANP} + \text{BNP}}{\text{Maximum biomass}},$$

where, ANP is the above-ground net primary production and BNP the below-ground net primary production. Turnover time was calculated by reversing the turnover rate calculation[2]. Statistical analysis using one-way ANOVA was done to detect differences between grassland types.

At Cherrapunji the differences between three grassland types, viz. the *Osbeckia*, *Arundinella* and *Ischaemum* types, are due to the decline in the frequency of fire. But where soil degradation is at its extreme, *Eragrostiella* type occurs[9]. Biomass and productivity declined with increase in the frequency of fire.

The biomass and productivity of the above-ground compartment of the *Osbeckia* type were the highest and those of the *Eragrostiella* type the lowest, the other two types falling in between; the differences between the four types were significant ($P < 0.05$) (table 1). However, biomass and productivity of below-ground compartment were significantly low ($P < 0.05$) for the *Eragrostiella* type compared to others; the other three grassland types, viz. *Osbeckia*, *Arundinella* and *Ischaemum*, did not differ significantly among themselves ($P > 0.05$). Even though, initially after the fire, there may be upward translocation of resources from below-ground parts of the perennial grasses, retranslocation would soon follow so that the annual below-ground biomass and productivity are not affected. The shoot/root ratio in the *Eragrostiella* grassland type as well as under *Arundinella* and *Ischaemum* types (subjected to fire) was low. This is obviously an adaptation to withstand stress due to perturbation caused by fire (*Arundinella* and *Ischaemum* type)[11] or due to low nutrient status of the soil (*Eragrostiella* type)[12]. It helps partly to increase root surface for better nutrient absorption[12] or for high vegetative reproduction[13].

Turnover rate for above-ground compartment improved in the order *Osbeckia*, *Arundinella*, *Ischaemum*, *Eragrostiella* (table 1). A higher turnover rate for the above-ground compartment of grasslands under stress would ensure effective recycling of nutrients, while lower turnover rates for below-ground parts would ensure storage of resources and thus help in survival. The annual turnover of biomass of the below-ground parts of about one or more than one is comparable to that of the above-ground parts, and agrees with that reported for another monsoonic grassland, from Kurukshetra, India[6]. This suggests that below-ground biomass is

Table 1 *Biomass, productivity and turnover patterns for above-ground (AG) and below-ground (BG) components of seral grasslands at Cherrapunji in northeastern India*

	Biomass ($g\ m^{-2}$)		Shoot/root	Productivity ($g\ m^{-2}\ y^{-1}$)		Turnover rate		Turnover time (year)	
	AG	BG	ratio	AG	BG	AG	BG	AG	BG
Osbeckia type	641 ± 29	1088 ± 81	0.59	579	990	0.90	0.91	1.11	1.10
Arundinella type	372 ± 26	1057 ± 42	0.35	420	986	1.13	0.93	0.89	1.07
Ischaemum type	306 ± 23	986 ± 71	0.31	357	932	1.16	0.94	0.86	1.06
Eragrostiella type	281 ± 25	734 ± 26	0.31	346	631	1.20	0.86	0.83	1.16

more dynamic in the tropics and is almost replaced every year, as much as the above-ground compartment. This is unlike the situation in, temperate grasslands, where the reported values are often much lower, ranging from 0.19 to 0.69[5].

It may be concluded that the arrested successional grasslands at Cherrapunji, which are subjected to a variety of stresses, show ecosystem properties adapted for survival under stress.

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