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Leaf phenology and biomass function of *Bambusa cacharensis* R. Majumder in subtropical humid climate of Assam, Northeast India

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Abstract: Leaf phenology and biomass increment of the culms of *Bambusa cacharensis*, a priority village bamboo was studied in the Cachar district of Assam, Northeast India. Leaf phenological parameters were associated with the seasonal changes. Leaf area expansion and leaf dry weight increment was greatest during warm and wet rainy season. Specific leaf area (SLA) exhibited inverse relation with leaf area and leaf dry weight. Pattern of biomass allocation changed with the culm maturity and culm phenology. Leaf and branch biomass showed the highest accumulation rate during the peak leaf appearance period while sheath, culm and total biomass showed the highest rate during the rapid phase of culm growth. Biomass acquisition is manifested by a shifting strategy of resource investment between culm and leaf component. Outcome of the study is discussed in the context to scientific management and efficient utilization of this bamboo species.

Key words: Phenology, biomass allocation, biomass accumulation, *Bambusa cacharensis*.

INTRODUCTION

Tropical plants often show temporal phenological patterns that are associated with well defined wet and dry season (Ratheke and Lacey, 1985). Leaf phenology, defined as the pattern and extent of variation of plant leaf area during a vegetation cycle, strongly influences carbon and water fluxes between vegetation and atmosphere and interactions among individual plants and individual species (Lechowicz and Koike, 1995). Leaf phenology is affected by the leaf type (deciduous and evergreen) and by environmental factors such as photoperiod, temperature, water status and atmospheric CO_2 concentration (Borchert, 1994; Eamus, 1999). Quantitative studies on leaf phenological variation in bamboo are scarce and that can play a critical role in understanding the species ecology. Despite the economic value and importance of bamboos in both tropical and temperate vegetation, little is known about the pattern of biomass allocation and biomass increment of growing bamboo (Shanmughavel

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and Francis, 1996). Quantitative knowledge of biomass increment of growing bamboo is a basic requisite for developing harvesting practices as for the reason that scientifically sound harvesting of bamboo culms can enhance its efficient utilization. *Bambusa cacharensis* R. Majumder is widely distributed and frequently cultivated bamboo species in the traditional homegardens and bamboo groves of Barak Valley (Nath and Das, 2008). Adaptability to different agro-climatic condition, rapid extension growth, desirable growth architecture and multiple uses made the species highest prioritized village bamboo of Barak Valley (Nath *et al.*, 2004). Present study was undertaken with the objective to understand the leaf phenological variation and pattern of biomass allocation and biomass increment in *B. cacharensis.*

MATERIALS AND METHODS

The study was conducted in a bamboo grove in the village Dargakona of Cachar district in South Assam, and is situated between longitude 92°45´ East and latitude 24°41´ North. The climate of the study site is subtropical, warm and humid. The region owes high rainfall mainly to south west monsoon, which usually operates for a longer spell in the North-Eastern region compared to other parts of the country. The monsoon rain normally starts from early June and continued to October. The mean maximum temperature ranges from 24.9°C (January) to 33.7°C (August) and the mean minimum temperature ranges from 11.8°C (January) to 24.8°C (July). The dry season usually occurs from December to February.

Present study was carried out in a pure patch of 12- year-old *B. cacharensis* stand. Leaf phenology, biomass allocation and biomass increment were studied during July 2002 – June 2004. Sixty nine newly sprouted culms were labelled with paints during July 2002 (period of peak culm emergence). Since all the 69 culms emerged almost together, the average values (quantitative data on phenology and biomass increment) from three culms were considered for present study over 23 consecutive harvests. During the two year study period, initially the culms were harvested at 15 days interval for first 150 days. Thereafter harvesting was done at one month interval for next 180 days and for last 420 days culms were harvested at two months interval. After the appearance of leaves, from the harvested culms, leaf size was determined on each harvest date by randomly sampling 300 leaves (100 from each culm). By plotting the values of leaf size in the regression equation ($y = -0.14+0.73x$, $r=0.99$, $P<0.001$) leaf area was calculated. The sampled leaves were then oven dried at 70°C to constant weight to calculate the leaf dry weight. Total leaf area (TLA) was estimated by multiplying the mean leaf area with the total number of leaves per culm. Specific leaf area (SLA) was calculated following Evans (1972) while leaf area ratio (LAR), leaf weight ratio (LWR), relative growth rate (RGR) and net assimilation rate (NAR) was calculated following Poorter and Remkes (1990).

For biomass study, culm, branch, sheath and leaf components were separated and fresh weight was determined in the field. Sub-samples were oven dried at 70°C to constant weight to calculate the oven dry weight of each component. Dry organic matter density was estimated following Othman (1993). Biomass accumulation rate was calculated as the ratio of change in dry weight per unit time.

RESULTS AND DISCUSSION

After the appearance of new leaves on the culm in September '02 (after two months of culm emergence) leaf area expansion and leaf dry weight increment gradually increased up to December '02 that remained stable up to March '03. With the beginning of peak leaf flushing (April '03), expansion in leaf area and increment in leaf dry weight continued that peaked around October '03 (12.36 cm^2 $leaf^{-1}$ and 0.1825 g $leaf^{-1}$ respectively). Leaf dry mass declined substantially during February-March '03 and '04 (Fig. 1a, b)). Thus, leaf phenological parameters differed considerably with seasonal variation. The rate of leaf area expansion was highest during April to August, suggesting greater efficiency of resource use and leaf energy balance strategies under warm and wet rainy season, which in turn associated with the more leaf dry matter accumulation and thus increasing the leaf dry weight. Similar pattern of leaf area expansion during the warm and wet rainy season was also reported in *Arundinaria falcata,* a common bamboo in 1200-1300 m a.s.l. in central Himalaya (Lodhiyal *et al.*, 1998). The peak photosynthetic activity is generally realized slightly before the completion of leaf expansion (Longman and Jenik, 1974). Leaf dry mass of *B. cacharensis* recorded two peaks and two declines throughout the study period. Mean leaf area and leaf dry weight across the study period was 9.02 cm^2 $leaf^{-1}$ and 0.05923 g $leaf^{-1}$ respectively.

SLA exhibited inverse relationship with leaf area and leaf dry weight (Fig. 1c). During the leaf senescence period, SLA peaked. During senescence the leaf mass loss raises the SLA to a substantial level (Lodhiyal *et al.*, 1998). Mean SLA across the study period was 154.16 cm^2 g^{-1}. SLA differed greatly from the reported SLA of 1321 cm^2 g^{-1} in *A. falcata* (Lodhiyal *et al.*, 1998). Differences in SLA can be ascribed to morphological factors like leaf thickness and vein structure.

TLA increased with the appearance of new leaves on the culm that peaked around December '03 (131526.4 cm^2 $culm^{-1}$). Thereafter, it declined (47826.12 cm^2 $culm^{-1}$) during April '04 (Fig. 1d). Mean TLA across the study period was 59833.4 cm^2 $culm^{-1}$. LAR and LWR across the study period was 15.81 m^2 kg^{-1} and 0.052 g g^{-1} respectively. LAR is partly determined by allocation (LWR) and partly by leaf morphology (SLA) (Poorter and Remkes, 1990). RGR and NAR across the study period was 5.86 mg g^{-1} day^{-1} and 4.19g m^{-2} day^{-1} respectively.

After 15 days from the time of new culm emergence (*i.e.*, in the first harvest) total biomass was allocated between culm (63.28%) and sheath (36.28%). Pattern of biomass allocation gradually changed and during the one-year age class of culm (*i.e.*, after 1

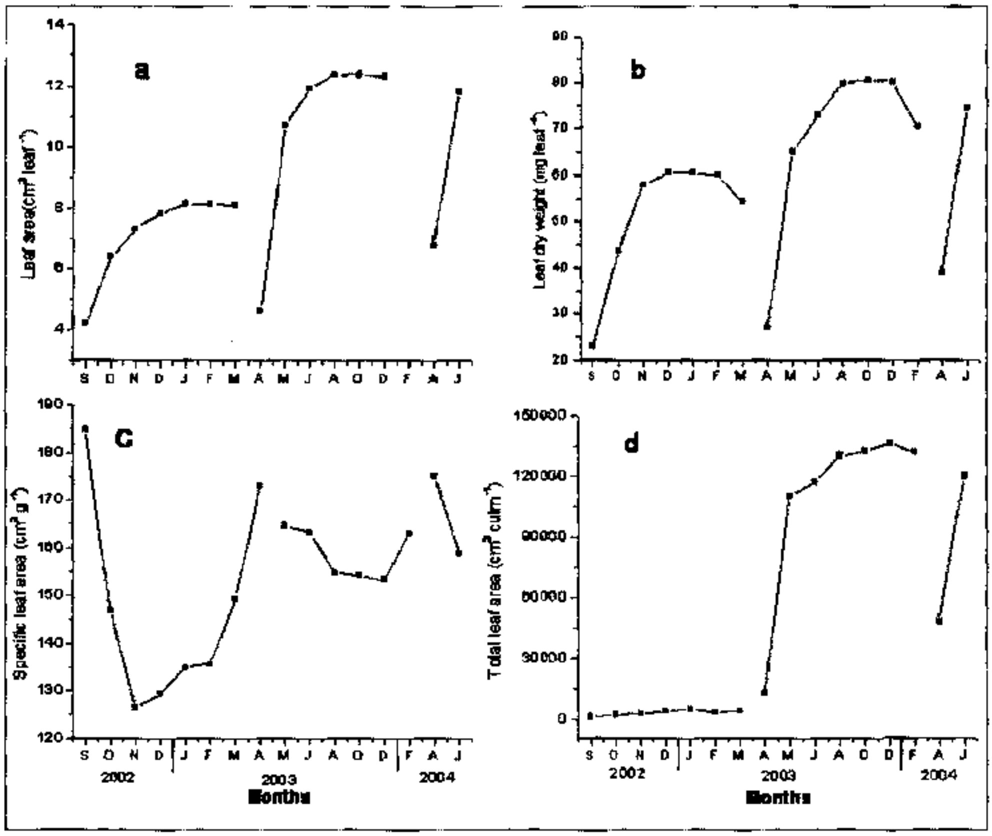

Figure 1. (a) Leaf area (cm^2 leaf^{-1}), (b) Leaf dry weight (mg leaf^{-1}), (c) Specific leaf area (cm^2 g^{-1}) and (d) Total leaf area (cm^2 culm^{-1}) for *B. cacharensis* during the two year study period.

year from the time of new culm emergence), total biomass was allocated between leaf (9.87%), branch (9.26%), culm (80.48%) and sheath (0.39%). Comparing the allocation pattern of first-year age class with the two-year age of culms (*i.e.*, at last harvest), total biomass was allocated between leaf (10.13%), branch (12.87%) and culm (77%). Thus, biomass allocation pattern is associated with the phenology and maturity of culms. Pattern of biomass allocation in *B. bambos* was culm (80-85%), branch (15-20%) and leaf (1%) (Shanmughavel and Francis, 1996). Differences in allocation of leaf biomass between *B. cacharensis* and *B. bambos* may be due to differences in the culm age class studied as well as differences in resource (water, light, nutrients, *etc.*) availability and its utilization efficiency by the plant.

Leaf biomass exhibited considerable variation with the seasonal changes throughout the study period. Sharp decline in leaf biomass is characterized by the period of peak leaf fall. Sheath biomass showed gradual increase up to the rapid phase of culm growth (about 100 days from the time of new culm emergence). During this period sheaths were light green in colour. With maturity, light green sheath turned into light brown and finally brown before falling off. Green sheath colour during rapid phase of culm growth can be an adaptive significance of this species under prevailing environmental condition towards higher resource utilization through greater photosynthetic efficiency (Nath *et al.*, 2008). Beginning of sheath fall subsequently declined the sheath biomass (Fig. 2). Culm and branch biomass exhibited almost increasing trend of biomass accumulation throughout the study period, indicating that biomass accumulation in these component has not been completed. The comparison of biomass structure of *B. cacharensis* with *Phyllostachys heteroclada* (Tienren *et al.*, 1987) culm biomass decreased after two years of age in the latter. Total above ground biomass of the two-year culm age classes in the present study was 8.37 kg culm^{-1}. The total above ground biomass of 3 to 4-years-old culms of *B. vulgaris*, *Gigantochloa levis* and *G scortechinii* was 6.4, 13.4 and 7.2 kg/culm^{-1} respectively (Mohmod *et al.*, 2002). The above ground biomass of *B. cacharensis* is within the range of these reported species, whereas it is about eight times lower than reported 67 kg culm^{-1} in *B. bambos* (Shanmughavel and Francis, 1996). The dry organic matter density of *B. cacharensis* was 0.28-0.91 kg m^{-3}. The reported dry organic matter density of *G. scortechnii* was 0.54-0.55 kg m^{-3} (Othman, 1993). Biomass accumulation rate per unit time exhibits the leaf and branch biomass accumulation that begins about 60 days after the culm emergence, has the greatest rate of accumulation 20.36 g day^{-1} and 6.37 g day^{-1} respectively during the peak leaf appearance on the culm (290th to 315th days of culm emergence). Negative leaf biomass accumulation rate around the 650th days of the study period was due to marked leaf fall during that period which in turn associated with the sharp decline in the total biomass accumulation rate. The rate of sheath and total biomass accumulation was also highest during the rapid phase of culm growth and the biomass accumulation rate was 2.94-7.49 g day^{-1}and 15.57-51.82 g day^{-1} respectively (Fig. 3).

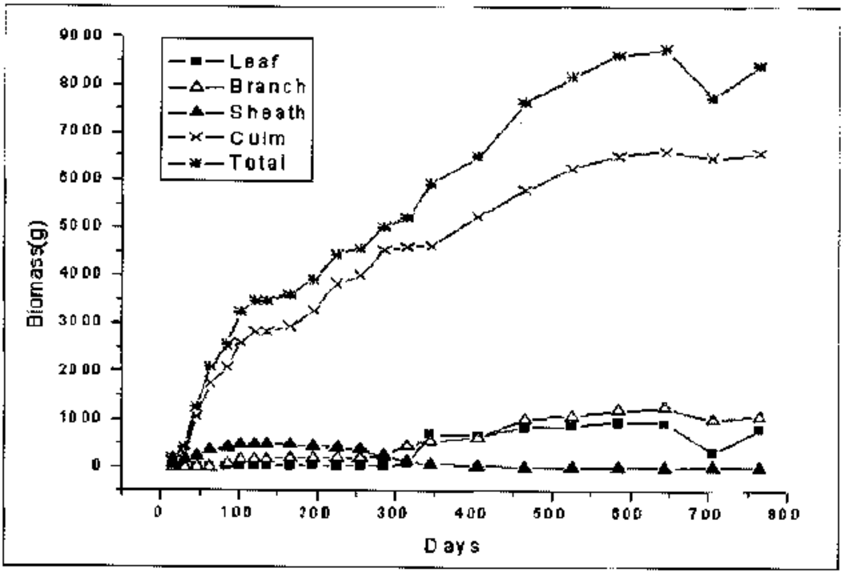

Figure 2. Biomass increment curves for different culm components of *B. cacharensis*.

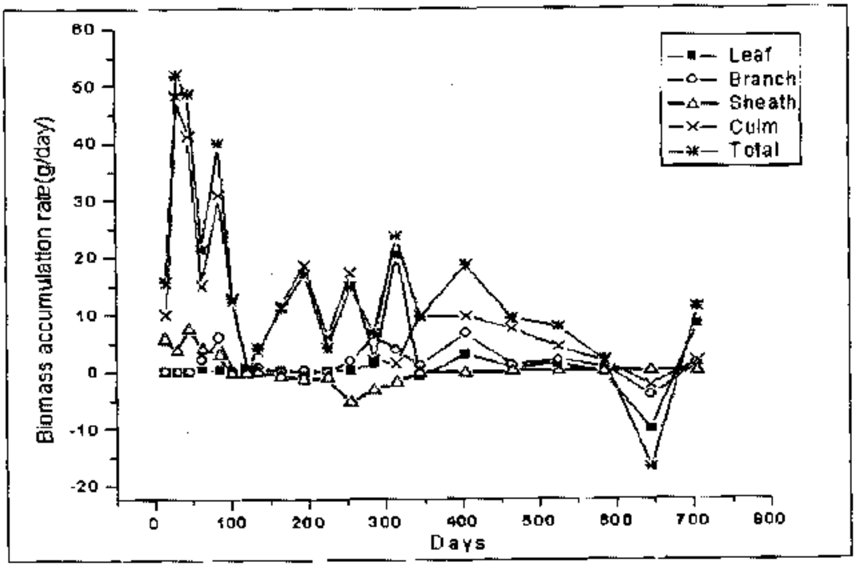

Figure 3. Biomass accumulation rate per unit time (g/day) for different culm components of *B. cacharensis.*

Culm biomass production increased at a greater rate during the rapid phase of culm growth that retained for about 100 days from its appearance. Peak growth rate during the rapid phase of culm growth in *B. cacharensis* varied from 15-28 cm per day (Nath *et al.*, 2004). During this period there was 21 fold increases in culm biomass from 119.44 g culm^{-1} (15 days old culm) to 2594.8 g culm^{-1} (102 days old culm) and culm biomass accumulation rate was 25.43 g day^{-1}. Thus rapid phase of culm growth rate is characterized by greater amount of biomass accumulation. During the next 180 days *i.e.*, beginning of peak leaf flushing, culm biomass accumulation rate gradually decreased and it was 10.55 g day^{-1}. During these 280 days, culm accounted 70 per cent of its total biomass. In the next 300 days (from peak leaf flushing to the highest leaf biomass accumulation period), the rate of culm biomass accumulation was 6.51 g day^{-1} and it accumulated 29 per cent of its total biomass, while leaf biomass accounted 97 per cent of its highest biomass. After peak leaf flushing, plant has the highest leaf biomass and thus highest amount of photosynthetic area and perhaps maximum of this photosynthate goes to the below ground *i.e.*, rhizome. Thus in *B. cacharensis* shifting strategy of biomass acquisition is manifested by more resource investment towards the culm component after the new culm emergence and then to leaf component for greater photosynthetic efficiency.

Like other tropical plants (Singh and Kushwaha, 2005) leaf phenological parameters of bamboo in the present study is associated with clear seasonality. Biomass increment pattern suggests that even at two years of culm age, culm component continues the process of dry matter accumulation. Thus, culms of less than two years are not suitable for efficient processing and optimum use. Such knowledge therefore can provide basic information for sustainable utilization and management of this keystone village resource through developing better silvicultural practices for enhancing greater biomass productivity.

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