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NITROGEN, PHOSPHORUS AND POTASSIUM FLUX IN THE CULMS OF *MELOCANNA BACCIFERA* DURING VEGETATIVE, REPRODUCTIVE AND SENESCENCE PHASES

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Abstract

Melocanna baccifera (Roxb.), the dominant bamboo species of Mizoram flowered gregariously during the year 2006-2009, Nitrogen (N), Phosphorus (P) and Potassium (K) content in the culms of M. baccifera were determined during vegetative, reproductive and senescence phases. The content of all the three macro nutrients were significantly higher in the non-flowering individuals followed by flowering and post-flowering individuals. N, P and K content in the non-flowering individuals show variations among the sampling months with higher value during the dry season. In case of flowering and post-flowering individuals, N, P and K decreased gradually from the first sampling to the rest of the study period. Mean N content in the non-flowering, flowering and post-flowering culms was 0.66%, 0.49% and 0.41% respectively, whereas mean P content was 0.60%, 0.33 and 0.17% respectively. Mean K content in the culms was recorded to be 0.37%, 0.14% and 0.06% respectively in non-flowering, flowering and post flowering individuals.

1. Introduction

Bamboo occupies as a predominant understory species in forest ecosystems of the north eastern India [1]. It serves as an important commercial source for a variety of purposes [2]. Melocanna baccifera (Roxb.) is an evergreen bamboo which is 10 to 20 m high and is distributed abundantly in north eastern (NE) India and cultivated in many Asian countries [3]. Flowering of this species have been occurred during 1863-66, 1892-93, 1900-02, 1910-12, 1933, 1960 [4, 5]. In the NE region flowering has been noticed during the years 1815, 1863, 1911, 1959 and 2000 [6]. Synchronized flowering involve a large fraction of the population, although some patches of non-flowered culms remain [7, 8] and is timed by an internal calendar possessed by each cohort of the bamboo [9]. This simultaneous flowering and death of bamboo leads to drastic changes in forest dynamics and environmental conditions [10]. Nitrogen, phosphorus and potassium are among the essential macro elements that limit the growth and productivity of plant communities by playing an important role in functioning of the ecosystem [11, 12, 13]. Nitrogen acts as most required element of bamboo followed by potassium and phosphate [14]. It is essential for many processes which are crucial for any life and in plants much of the nitrogen is used in chlorophyll molecules, which are essential for photosynthesis and further growth [15] and necessary for the functioning of biochemical pathways including chlorophyll complex, enzymes and nucleic acids [16]. Phosphorus involves in energy transfer and acts as important building blocks of genes and chromosomes [17]. Potassium acts as a booster element in uptake and transport of other nutrients [18]. It also involved in carbohydrate production and partitioning and the anion or cation balances [19]. It also helps in the improvement of hardiness and durability of plants [20].

Studies on nutrients and flowering phenomenon in bamboos are very limited due to long gap between the consecutive flowering cycles. The relationships between plant nutrients and bamboo flowering or death of bamboos after flowering are still indistinct and yet to be studied. Therefore, it became indispensable to assess the nutrient contents when bamboo endures through three different phases i.e. pre-flowering, flowering and post flowering stages. Considering the requirements, this study has been carried out to understand the status of the three important macronutrients (N, P and K) in culms of M. baccifera during pre-flowering i.e. vegetative phase, flowering i.e. reproductive phase and post flowering i.e. senescence or death phase. This study may clarify the role of primary macronutrients on bamboo flowering considering M. baccifera as a model bamboo species.

2. Materials and Methods

The study was carried out at Mammit and Champhai district of Mizoram, India where Melocanna bacciferra (Roxb.) flowered gregariously during 2006-2009. Study site is located between 23053’ N to 23054’39.5” N latitude and 92028’36” E to 92029’55” E longitude with a mean elevation of 745 m above mean sea level in Mammit whereas in Champhai district sampling sites were located one at 23037’45.5” N latitude and 93004’21.5” E longitude with 828 m above mean sea level and another at 23047’31.5” N latitude and 93009’25.3” E longitude with 655 m above mean sea level.

Three replicate sampling sites were identified for each phase, i.e. non-flowering (NF), flowering (FL) and post flowering (PF)clumps of M. baccifera and they were earmarked using GPS (76xMap, Garmin). Samples of bamboo culms of M. baccifera for the three different phases were collected considering different age groups at an interval of three months (seasonal basis) starting from October 2008 till July 2010. The collected samples were dried and ground to powder form using a Willey's mill. The ground samples of different culm age group for each clump were mixed thoroughly for respective sites and phases. Determination of plant nitrogen content was carried out by following micro-Kjeldhal method as described by [21] Allen et al., (1974) using KEL PLUS nitrogen analyzer. Phosphorus content in the culm was determined by Molybdenum blue method following Allen et al. (1974) using UV-VIS spectrophotometer (Labomed, USA). Potassium content was determined by flame photometer (SYSTRONICS) following Allen et al., (1974). All the data obtained were statistically analysed using multi-way ANOVA to understand their significant levels.

3. Results

Variation in nutrient concentration in culms of M. baccifera during non-flowering, flowering and post-flowering phases are presented in figure 1, which shows that N, P and K content were significantly higher in non-flowering culms than the flowering and post-flowering culms. Nutrient content in the culms of M. baccifera during the three phases i.e. non-flowering, flowering and post-flowering were in the order of NF>FL>PF. Concentration of nitrogen in culms of M. baccifera differed significantly among the three phases ($F = 41.210$, $P< 0.001$) and between two study years ($F = 45.469$, $P< 0.001$). The variation due to interaction values between phase and year were significant ($F = 5.622$, $P< 0.01$) (Table 1), however, phases and sampling month, month and year as well as phase, month and year were not significant.

Table 1: Nitrogen content (%) in the culms of three phases of *M. baccifera*

Dep Var: NITROGEN N: 72 Multiple R: 0.873, multiple R^2: 0.761
Analysis of Variance

Source	Sum of Squares	DF	Mean-Square	F-Ratio	p
Phase	0.726	2	0.363	41.210	0.000*
Month	0.051	3	0.017	1.939	0.136
Year	0.401	1	0.401	45.469	0.000*
Phase*Month	0.045	6	0.008	0.851	0.537
Phase*Year	0.099	2	0.050	5.622	0.006**
Month*Year	0.015	3	0.005	0.582	0.629
Phase*Month*Year	0.012	6	0.002	0.224	0.967
Error	0.423	48	0.009		

(*p< 0.001 and ** P< 0.01)

Table 2: Phosphorus content (%) in the culms of three phases of *M. baccifera*

Dep Var: PHOSPHORUS N: 72 Multiple R: 0.936, multiple R^2: 0.876
Analysis of Variance

Source	Sum of Squares	DF	Mean-Square	F-Ratio	p
Phase	2.304	2	1.152	135.697	0.000*
Month	0.067	3	0.022	2.623	0.061
Year	0.213	1	0.213	25.123	0.000*
Phase*Month	0.069	6	0.012	1.357	0.251
Phase*Year	0.183	2	0.091	10.760	0.000*
Month*Year	0.006	3	0.002	0.246	0.864
Phase*Month*Year	0.041	6	0.007	0.801	0.574
Error	0.408	48	0.008		

(*p< 0.001 and ** p< 0.01)

Table 3: Potassium content (%) in the culms of three phases of *M. baccifera*

Dep Var: POTASSIUM N: 72 Multiple R: 0.97, multiple R^2: 0.941
Analysis of Variance

Source	Sum of Squares	DF	Mean-Square	F-Ratio	p
Phase	1.252	2	0.626	346.595	0.000*
Month	0.052	3	0.017	9.663	0.000*
Year	0.026	1	0.026	14.639	0.000*
Phase*Month	0.023	6	0.004	2.111	0.069
Phase*Year	0.025	2	0.013	7.028	0.002**
Month*Year	0.007	3	0.002	1.259	0.299
Phase*Month*Year	0.002	6	0.000	0.171	0.983
Error	0.087	48	0.002		

(*p< 0.001 and ** p< 0.01)

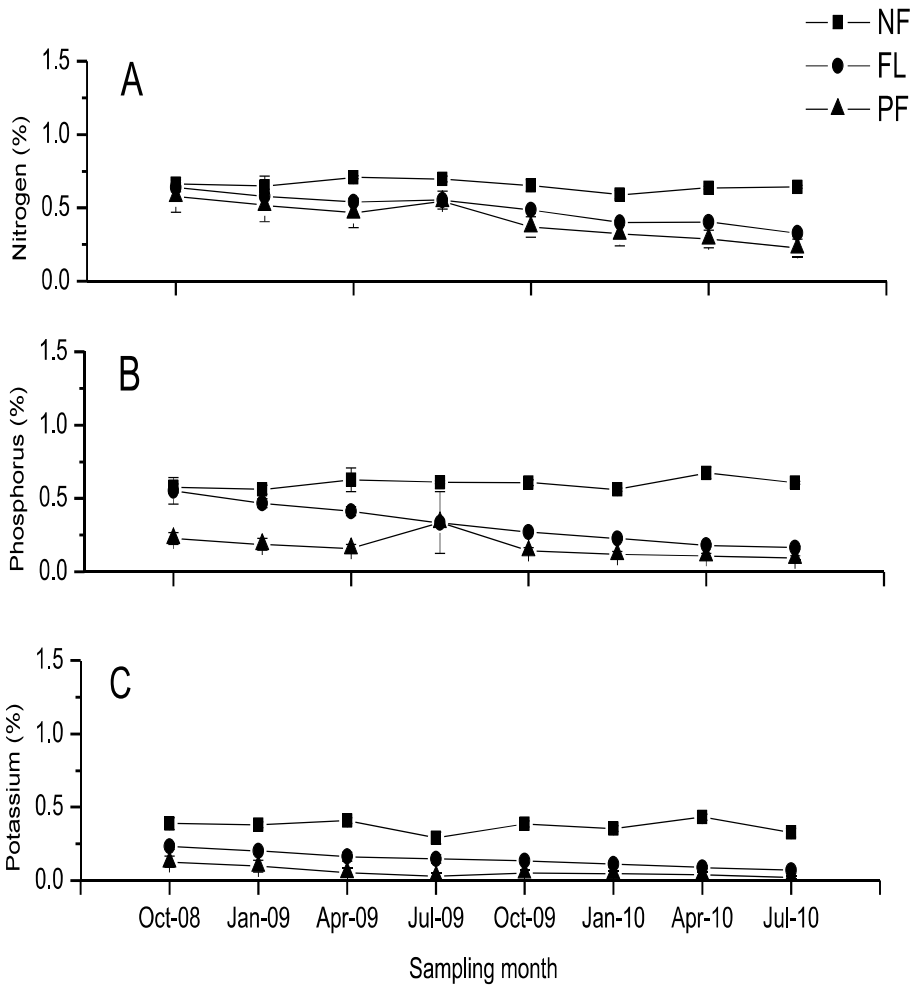

Figure 1: Nitrogen (A), Phosphorus (B) and Potassium (C) content in the Non-flowering (NF), Flowering (FL) and Post-flowering (PF) culms of Melocanna baccifera collected from Mizoram during different months (Mean ± SE).

Nitrogen concentration in non-flowering, flowering and post flowering culms was in the order of NF>FL>PF. The data on the concentration of nitrogen revealed that non flowering culms of M. baccifera show the highest mean concentration 0.66%, followed by flowering culms with 0.49% and post-flowering bamboos show the lowest value with 0.41%, respectively. During different sampling months, the highest nitrogen concentration at non flowering culms was observed during the month of April (2008-09) with 0.71%, October (2008-09) was observed having highest concentration for both flowering and post flowering culms with 0.64% and 0.58% respectively. The lowest concentration for non flowering was recorded during the month of

January (2009-10) with 0.59% and July (2009-10) was observed for both flowering with 0.33% and post flowering with 0.23% (Figure 1A).

Figure.1(B) represents the variation in phosphorus content in the culms of M. baccifera during non-flowering (NF), flowering (FL) and post-flowering (PF) phases. The difference in phosphorus concentration was significant among different phases ($F = 135.697$, $P< 0.001$). It was also significantly different between study years ($F = 25.123$, $P< 0.001$). The values of interaction between phases and study years were significant ($F = 10.76$, $P< 0.001$), however, different phases and sampling months, sampling months and study years as well as phases, sampling months and study years were not significant (Table 2). Variation in phosphorus concentration in non-flowering culms of M. baccifera showed the highest mean of 0.60%, followed by flowering culms with 0.33% and post-flowering bamboos showed the lowest value with 0.17% (Fig.1 B). Highest P concentration in non-flowering culms was observed during the month of April (2010) with 0.67%, October (2008) showed the highest mean for flowering culms with 0.55% and July (2009) was observed highest for post flowering culms with 0.34%. The lowest concentration was recorded during the month of January (2009 and 2010) with 0.56% for non-flowering culms and July (2010) was found lowest for flowering culms with 0.16% and followed by post flowering culms with 0.09%. Phosphorus concentration in non-flowering, flowering and post flowering culms was in the order of NF> FL> PF.

Potassium concentration differed significantly among different phases ($F = 346.595$, $P< 0.001$), different sampling months ($F = 9.663$, $P< 0.001$) and different sampling years ($F = 14.639$, $P< 0.001$) Figure 1 (C). The values of interaction between different phases and sampling years were significant ($F = 7.028$, $P< 0.01$), although, interaction between different phases and sampling months, sampling months and sampling years as well as different phases, sampling months and sampling years were insignificant (Table 3). Highest potassium concentration was found at non-flowering culms with the mean of 0.37%, followed by flowering culms with 0.14% P and least in post flowering culms with 0.06%. The highest K concentration was observed during the month of April (2010) in non-flowering culms with 0.43%, October (2008) was recorded highest for flowering culms with 0.23% and post flowering culms with 0.13%. Lowest potassium concentration was observed in non-flowering culms during July (2009) with 0.29%, whereas for flowering culms 0.07% and post flowering 0.02% were recorded during the month of July (2010) (Figure 1C). Potassium concentration in non-flowering, flowering and post flowering culms was in the order of NF> FL >PF.

4. Discussion and Conclusions

Our findings indicate that concentration of plants nitrogen, phosphorus and potassium contents were more in non-flowering culms of M. baccifera in comparison with culms of flowering (i.e. reproductive phase) and post flowering (i.e. senescence phase) phases of M. baccifera. Nutrient concentrations in non-flowering culms varied during seasons, however, flowering and post flowering phases showed a gradual decrease in their nutrient concentration. Concentrations of nutrients were highest in non-flowering (vegetative) culms which were similar with the view of [22]. The study showed a significant decrease in nutrient after the onset of flowering. These findings are in agreement with earlier reports [9, 22, 23, 24]. Generally, bamboo nutrient content decreases with increasing age which also associates with the decline of photosynthetic activity in leaves [25, 26, 27]. Our findings might be correlated with the observation of [28] who reported peak N, P and K concentrations in plantation bamboo at the bud stage, which decline during organ expansion stage. Bamboo does not produce new vegetative culms prior to a year before flowering [29, 30, 31] and leaves are dropped for a year and subsist off reserves stored in the rhizome or photosynthate from a few leafy stems [9] and leaf development also ceases when it reaches flowering stages [32] as well as growth and development are seizes due to the transition of the apical meristem into massive inflorescence followed by seeding [24]. The above observations might have impacts on the nutrient cycling in flowering and post-flowering phases. During these periods, reproductive organs serve as resource sinks that might be obtained from the nearest vegetative organs during flowering and fruiting. This is in conformity with the findings of many workers [33, 34, 35, 36]. As a consequence of such activities might result to the cessation of nutrient uptake after mass flowering [37] in which adult mass-seeding bamboo die after bearing seed in mast year [9]. Therefore in bamboo, death may be caused by reproductive exhaustion caused by the movement of food reserves from the vegetative parts [24], consequently, in case of M. baccifera large amount of seeds were set during the period and the view of [24] may be one of the reason for the decline of nutrients in the flowering phases.

Large amount of P is needed for seed and fruit formation and development where these might be up-taken from rhizome and culms of bamboo. When P decreases the movement of nutrients within plant decreases as it requires energy to oppose the forces of osmosis, which were supplied by P [17], in addition root growth is also reduced by P deficiency, leading to fewer roots mass to reach water and nutrients. The same chemistry might happen in the flowering bamboos which eventually result in the death of bamboo after flowering. A gradual decrease in K were also seen in flowering and post-flowering culms, such reduction in K might affect the rate of photosynthesis and conclusively on the rate of ATP production affecting again other metabolic process which depends on ATP. Potassium deficiency could be incorporated with the low K in soil due to compaction, low soil pH, root injury, etc. [38] and K being a mobile nutrient in the plant, it will translocated from older tissues to young growing tissues. Low K levels might also affect in the type and quantity of amino acids translocated in the phloem [39]. Therefore, in the case of M. baccifera nutrient uptake might be seized after the seed shed leading to the limited availability of

primary macronutrients and finally die off. Such activity of flowering might degrade the quality and prone to diseased. Death after mass flowering of bamboo is common in most of the species including M. baccifera leading to die-off all the flowered clumps and subsequently dried in the environment. During our study, continuous loss of nutrients was observed after the onset of flowering and therefore it may be concluded that primary macronutrients (N, P and K) play a significant role in the survival of culms, however, direct relationship with nutrients, flowering and death of bamboo after flowering is yet not clear. In fact, it would be more precise to include the role of nutrient cycling in soil because in forest ecosystem nutrient cycling is strongly depends on litter and soil organic decomposition [40]. To support the argument, the findings of [37] may be useful who observed low nitrogen concentration in soil of bamboo flowered and death site. This also might be due to less inputs of fast decomposing matter such as foliage, fine roots, and twigs etc. [41, 42] which were once supplied by bamboo.

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