Research Article

Nitrogen Use Efficiency, Nutritive Value of Leaves and Survival of Moso Bamboo (*Phyllostachys pubescence*) Seedlings under the Influence of N-Fertigation

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Abstract

The study investigated the nitrogen use efficiency, nutritive value of leaves and survival of Moso bamboo (*Phyllostachys pubescence*) seedlings under the influence of N-fertigation in temperate condition of Kashmir. The experiment was undertaken at Faculty of Forestry, Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir, Benhama, Ganderbal, Kashmir. The rhizomes of *Phyllostachys pubescence* extracted before sprouting of new buds were immediately transplanted in the poly bags. The established seedlings were fertigated with the different nitrogen levels *viz*., 0, 3, 6, 9, 12, 15, 18 and 21mg dissolved in 50 ml of water along fixed levels of P, K, Ca and Mg seedling^{-1} week^{-1} up to 28 weeks. The nitrogen (N) use efficiency decreased proportionately with increase in the content of N used for fertigating the seedlings. The minimum N use efficiency of 181.768 was recorded in seedlings fertigated with 21 mg N seedling^{-1} week^{-1}. This value was around 3.13 times higher for seedlings raised under 3 mg N seedling^{-1} week^{-1}. Relative growth rate also increased with the increase in N-fertigation. Seedlings fertigated with 21mg N seedling^{-1} week^{-1} recorded maximum *i.e.* about three times more nutrient content in the leaves *viz*., 2.98% nitrogen, 1.57% phosphorus, 1.70% potassium, 0.32% calcium, 0.21% magnesium, 18.53% crude protein and 2.483% ash content as compared to control. N-fertigation significantly affected seedling survival with maximum average seedling survival of 92.72 % with 18mg N seedling^{-1} week^{-1} which was 1.11 times more than control.

Keywords: Nitrogen use efficiency, nutritive value, Moso bamboo, *Phyllostachys pubescence*, N-fertigation

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Introduction

Bamboo is a major Non-Timber Forest Product (NTFP) whose exploitation provides local people with sufficient food and fodder and contributes to the development of herbal medicine as well as generates income [1] and is an exceptionally fast growing plant, which allows harvesting for construction within 4-7 years [2]. Bamboos have versatile uses and a wide range of ecological amplitude distributed throughout the tropical, sub-tropical and cold temperate regions except in Europe, from sea level to 4000 m [3]. It has about 70 genera divided into about 1,500 species of bamboo all over the world [4]. A total of 20 genera and 115 species of bamboos are found in India [5]. They are particularly abundant in the Western Ghats and the “Sister States” of north-east India [6]. China has the highest (626 species) bamboo diversity followed by India (102) and Japan (84) [7]. About 50% of the annual production of bamboo in our country is used by various industries like pulp, paper, rayon, mat boards, besides agricultural implements. It is also used for making baskets, bridges, coffins, beds, toys and weapons [8]. Besides particle board material and substitute for rattan, pickled or stewed bamboo shoots are regarded as delicacies in many parts of the country. The major user of bamboo in India is paper industry, which consumes sizeable proportion (20%) of the total annual bamboo production. Bamboos are good soil binders owing to their peculiar clump formation and fibrous root system and therefore, play an important role in soil and water conservation Furthermore, bamboo tolerates poor soils, which makes it useful for planting on degraded soils [9].

Moso bamboo (*Phyllostachys pubescence*) is the most important bamboo species in China, its aerial shoots are long-lived, persisting aboveground for more than ten years [10]. The species originates from China and has been naturalized in some other neighboring countries, such as Korea and Vietnam. Economically Moso bamboo is the most important bamboo species in the world. In India Moso bamboo is a prioritized species under National Bamboo Mission and has been included in bamboo for PAN India plantation Program under which it has been planted in sub temperate zones of Arunachal Pradesh and Himachal Pradesh. Applications include bamboo flooring that is produced in China and exported to the United States and Europe. It is also widely cultivated for production of shoots, which is considered a delicacy throughout Asia. Moso bamboo is a key species for rural and industrial development, particularly in south-eastern parts of China. Recommendations of N fertigation vary widely. The fertilizer often provide actual N requirement and thus more frequent doses accompanied with tissue analysis to determine concentration needed for optimum growth [11]. Fertilization is the most important management technique for obtaining greater biomass production [12]. Nutrition of tree seedlings growing in nursery has to be balanced to meet the needs of the growing plant. Studying the efficient use of the fertilizers to achieve maximum growth can economize production by decreasing fertilizer inputs and their run off. It is generally recognized that effective fertilizer management includes nutrient application appropriate to various stages of plant growth because young seedlings are generally diluted to half strength of recommended concentration during initial stages of growth, after which fertilizer can be applied at regular strength. The biomass production in response to increasing N fertigation generally follows a typical yield response curve with low biomass at no or low N rates and increasing biomass with increasing N rates up to a steady state or luxury consumption where biomass is not increased with increasing N rates [13]. Most fertilization regimes apply nutrients in split application of equal amounts at predetermined time intervals, with goal of steady-state nutrition. The perusal of literature reveals that no consolidated account on N fertigation is available on Moso bamboo (*Phyllostachys pubescence*) or any other temperate bamboo species. Keeping in view the utilization of bamboo and its valuable socio-economic and environmental benefits the present investigation was undertaken to see the effect of N-fertigation on N-use efficiency and nutritive value of leaves and survival in Moso bamboo.

Materials and Methods

The present investigation was conducted in the nursery of Faculty of Forestry, Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir, Benhama, Ganderbal, during the year 2015-2016. The experimental site is located at 34°17′ N latitude and 74°46′ E longitude with 1617 m altitude above the mean sea level. The site falls in the temperate zone. The winter starts from November to February with severe cold and frost in the month of January. The mean maximum temperature is 29.8° C and minimum temperature is -1.92° C with July and January as hottest and coldest months, respectively. The average precipitation of the study site is 690 mm mostly in the form of snow during winter months. The rhizomes of *Phyllostachys pubescence* before sprouting of new buds were extracted from the nursery of Agricultural Production Department, Government of Jammu and Kashmir, Budgam in the last week of February 2015 and were immediately transplanted in the poly bags of size (10cm × 15cm) filled with soil. The well-established clumlets were treated weekly with nitrogen fertigation and continued till end of growing season. The seedlings were applied with 0, 3, 6, 9, 12, 15, 18 and 21 mg of nitrogen per seedling and fixed levels of P (0.39 mg), K (1.95 mg), Ca (0.21 mg) and Mg (0.25 mg) seedling^{-1} week^{1} (**Table 1**). Nutrient fertigation was applied weekly @ 50 ml seedling^{-1}. Suitable control was also maintained and applied with plain water. Each treatment was replicated three times with 50 polybags in each replication. All cultural operations were viz., weeding, irrigation, etc. were carried as and when required. Nine seedlings from each treatment were selected randomly and harvested to record the observations.

Table 1 Treatment details of the experiment

Treatment code		Description
T_0	:	Control (no fertigation)
T_1	:	N (0) mg + P (0.39) mg + K (1.95) mg + Ca (0.21) mg + Mg (0.25) mg
T_2	:	N (3) mg + P (0.39) mg + K(1.95) mg + Ca(0.21) mg + Mg (0.25) mg
T_3	:	N (6) mg + P(0.39) mg + K (1.95) mg + Ca (0.21) mg + Mg (0.25) mg
T_4	:	N (9) mg + P(0.39) mg + K (1.95) mg + Ca (0.21) mg + Mg(0.25) mg
T_5	:	N (12) mg + P(0.39) mg + K(1.95) mg + Ca(0.21) mg + Mg(0.25) mg
T_6	:	N (15) mg + P(0.39) mg + K(1.95) mg + Ca(0.21) mg + Mg(0.25) mg
T_7	:	N (18) mg + P(0.39) mg + K(1.95) mg + Ca(0.21) mg + Mg(0.25) mg
T_8	:	N (21) mg + P(0.39) mg + K(1.95) mg + Ca(0.21) mg + Mg(0.25) mg

Values in parenthesis are different values of nutrients applied

Results

The cumulative amount of nitrogen added by treatments varied from 84.00 to 588.00 mg per seedling up to the time seedlings were harvested at 28 week of age. As the concentration of N in treatments increased the nitrogen use efficiency (NUE) in *Phyllostachys pubescence* seedlings decreased from lowest addition rate 569.011 mg of biomass mg^{-1} of N in T_2 to 181.786g mg^{-1} N in treatment T_8 at highest rate. In contrast to it the relative growth rate increases with increase in nitrogen concentrations however relative growth rate at higher concentrations remains the same. The data (**Table 2**) revealed that nitrogen fertigation significantly ($p \leq 0.05$) affect nutrient content of *Phyllostachys pubescence* leaves. The maximum nitrogen content 2.98 per cent was recorded in seedlings fertigated with 21mg of nitrogen (T_8) and minimum 0.823 in control (T_0). The increase is about 3.617, however, there is no difference between T_2 and T_3, T_4 and T_5 and T_7 and T_8 (**Figures 1** and **2**).

Table 2 Effect of Nitrogen fertigation on nitrogen use efficiency and relative growth rate of *Phyllostachys pubesence* seedlings

N-fertigation levels (mg seedling^{-1})	Nitrogen use efficiency	Relative growth rate (g/ week)
$T_{0} = (0.00)$	-	0.055
$T_{1} = (0.00)$	-	0.057
$T_{2} = (3.00)$	569.011	0.063
$T_{3} = (6.00)$	361.208	0.069
$T_{4} = (9.00)$	288.781	0.073
$T_{5} = (12.00)$	241.169	0.075
$T_{6} = (15.00)$	224.850	0.078
$T_{7} = (18.00)$	212.910	0.078
$T_{8} = (21.00)$	181.768	0.078

Figure 1 Bamboo seedlings

Figure 2 Quality plant material

Phosphorous content has also increased many folds, the maximum concentration of 1.57 per cent was recorded in T_8 which was about 2.97 than the control that is when no nitrogen was applied although the treatments T_0 and T_2, T_4 and T_5 and T_7 and T_8 are at par with each other (**Table 3**). Similar trend was observed for potassium the maximum K content 1.57 was recorded in T_8 which was 2.760 times greater than 0.617 per cent in control (T_0). The treatment T_0 and T_1 and T_7 and T_8 are statistically at par. Calcium content has also increased with the increase in fertigation dose the maximum calcium content 0.321 per cent was recorded in (T_8) and minimum (0.100) was recorded in control (T_0). However, T_7 and T_8 were statistically at par. The similar trend was observed in case of Magnesium, the maximum Mg content was recorded in (T_8) followed by (T_7) and minimum content in control (T_0) the maximum 0.210 per cent recorded in T_8 was 3.5 times than control (T_0) which is 0.060 per cent.

Crude protein content also varied significantly with increasing level of nitrogen with the maximum (18.553%) crude protein content in T_8 having about 3.597 greater than control T_0 which was 5.157 per cent. However, T_2 and T_3, T_5 and T_6, T_7 and T_8 were at par with each other and does not show any difference besides ash content has also increased the maximum content was recorded in T_7 (2.483) followed by T_8 (2.230).

The **Table 4** reveals that nitrogen fertigation significantly affected seedling survival ($p \leq 0.05$) in *Phyllostachys pubescence* seedlings. Maximum average seedling survival of 92.72% was recorded at T_7 which was 1.11 times more than control T_0 (83.43%) but T_8 and T_7 does not show any statistical difference. The effect of age on seedling survival showed significant difference. The maximum seedling survival 99.78% was recorded at 4 weeks of age which decreased continuously and reached to 78.28% at 28 week of age. The interaction effect of nitrogen fertigation and age shows significant difference on survival per cent of *Phyllostachys pubescence* seedlings.

Table 3 Effect of nitrogen fertigation on nutrient content of *Phyllostachys pubescence* leaves under different nitrogen addition rates after seven months

N-fertigation levels (mg seedling^{-1})	N concentration (%)	P concentration (%)	K concentration (%)	Ca concentration (%)	Mg concentration (%)	Crude protein content (%)	Ash content (%)
$T_{0 = (0.00)}$	0.823	0.530	0.617	0.100	0.060	5.157	1.247
$T_{1 = (0.00)}$	1.090	0.577	0.670	0.128	0.064	6.810	1.513
$T_{2 = (3.00)}$	1.360	0.607	0.870	0.157	0.090	8.460	1.630
$T_{3 = (6.00)}$	1.540	0.750	1.073	0.173	0.110	9.630	1.760
$T_{4 = (9.00)}$	1.873	0.890	1.243	0.213	0.123	11.737	1.850
$T_{5 = (12.00)}$	2.050	0.997	1.360	0.230	0.147	13.143	1.910
$T_{6 = (15.00)}$	2.300	1.330	1.610	0.269	0.170	14.377	2.040
$T_{7 = (18.00)}$	2.860	1.531	1.647	0.318	0.183	17.793	2.230
$T_{8 = (21.00)}$	2.977	1.573	1.703	0.321	0.210	18.533	2.483
C.D ($p \leq 0.05$)	0.224	0.124	0.070	0.004	0.026	1.307	0.082

Table 4 Effect of nitrogen-fertigation and age on survival (%) on *Phyllostachys pubescence* seedlings

N-fertigation levels (mg seedling^{-1})	Age (weeks)							Mean
	4	8	12	16	20	24	28	
$T_{0 = (0.00)}$	98.00	96.00	90.00	80.00	75.67	73.00	71.33	83.43
$T_{1 = (0.00)}$	100.00	98.00	91.00	80.00	76.33	74.00	73.17	84.64
$T_{2 = (3.00)}$	100.00	98.00	92.00	81.00	76.40	75.50	74.00	85.27
$T_{3 = (6.00)}$	100.00	98.20	94.00	82.00	78.00	76.23	74.00	86.06
$T_{4 = (9.00)}$	100.00	98.23	94.00	85.00	83.00	81.50	79.00	88.68
$T_{5 = (12.00)}$	100.00	98.33	94.20	87.00	85.00	82.00	80.03	89.51
$T_{6 = (15.00)}$	100.00	98.50	94.50	90.00	88.00	84.70	81.00	90.96
$T_{7 = (18.00)}$	100.00	98.70	95.00	92.00	90.00	87.33	86.00	92.72
$T_{8 = (21.00)}$	100.00	98.27	95.00	91.00	89.67	87.00	86.00	92.42
Mean	99.78	98.05	93.30	85.33	82.45	80.14	78.28	
C.D ($p \leq 0.05$)								
Fertigation :	0.48							
Age (weeks) :	0.42							
Fertigation × Age :	1.27							

Discussion

Nitrogen is major constituent of enzymes and change in nitrogen concentration of tissue generally reflects change in enzymes concentration. Both gross primary production and plant respiration represents biochemical processes that are catalyzed by nitrogen rich enzymes; the rate of these processes depend, in part, on the nitrogen content of tissues. Also because of construction of new tissue requires nitrogen in addition to carbon, gross primary production may depend on the nitrogen status of the plant. Nitrogen status is influenced by its availability and uptake. Thus nitrogen may play role in the response of net primary production by influencing tissue and plant processes. Higher level of nitrogen availability generally increases the nitrogen concentration of leaves, which increases the growth of the plants [14]. Availability of nitrogen and CO_2 interact to affect the exchange of carbon between the plant and atmosphere on per unit leaf area basis and influence the growth and biomass allocation [15]. Preplant nutrient fertilization practices play an important role in the production of quality seedling [16]. Fertilization can modify tissue nutrient contents and the amount of available reserves, improves post-transplant rooting and growth capacity of seedling [17].

Nitrogen use efficiency has decreased from 569.011mg of total biomass mg^{-1} per unit of N in T_2 to 181.768mg of total biomass mg^{-1}per unit of N in T_8 as the nitrogen addition rates increase from 84mg of nitrogen to 588mg Nitrogen from T_3 to T_8. High nutrient use efficiency is an adaptive strategy to tolerate nutrient stress with plant species often exhibiting the highest nutrient use efficiency to tolerate nutrient stress at low levels of soil fertility [18]. The NUE estimation of eight tree species by using the inverse of nutrient concentration in litter fall indicted that the red pine had the highest NUE on sites with the lowest N availability [19]. Conversely, high fertility levels are used during production phase to increase growth rate, thereby, decreasing rotation time and presumably increasing nursery profitability high fertility levels increase shoot/root ratios, enhance tissue N concentration and alter N distribution within the plants thereby causing relatively more N to be in partitioned into shoot portions and less into the root [20]. Our results corroborate with the study [21] which found the red oak and black gum seedlings produced at lower N application rates had higher N use efficiency but were smaller than seedling produced at higher N application rates. The study [22] has also determined that nitrogen use efficiency (NUE) of loblolly pine (*Pinus taeda* L.) seedlings increased as N availability decreased. Results are also in conformity with the findings [23] who reported that the nutrient use efficiency in Neem seedlings decreased with the increase in nutrient supply. The N use efficiency of 57.47 per cent in *Cedrus deodara* and 100.14 per cent in *Cupressus torrulosa* at 9 mg N addition rate were found [24]. The results of present study are also in consistent with the study [25] who reported that NUE of whiter pine seedlings decreased with increase in concentration of N in tissues. Difference in NUE may also result from difference allocation levels. Leaves with maximum photosynthesis rate may invest a large proportion of the leaf in Rubisco. Low NUE may be a result of inefficient allocation of N among photosynthetic compounds, such that some compounds are in excess, while the rate limiting compounds are underrepresented. For example, shade plants invest large quantity of N in light harvesting pigments and proteins, but make only small investment in Rubisco and other CO_2 processing enzymes [26].

The study on the adaptation and physiology response of wild plants to nutrient stress and revealed that the species which absorb nutrients in excess of growth requirements (luxury consumption) may use these reserves to support growth after soil reserves are exhausted. This conservation strategy may decrease nutrient use efficiency (g mass/g nutrient) immediately but may be beneficial for growth when the soil reserves are exhausted and thus ultimately would have the potential to contribute to future productivity [27]. The optimum range of nitrogen requirement in correspondence to optimum growth rate varies with the species, for instance the optimum N content varies between 200-400 mg NL^{-1} for red maple [28], 8-20 mg NL^{-1} for *Cupressus torulosa* and *Cupressus arizonica* [24]. Nutrient pools in vegetation are the function of standing biomass, the nutrient concentration and the relative allocation pattern of this biomass to different vegetation components. The measurement of these nutrient pools provides information on the biomass of nutrients immobilized in plant biomass and the amounts required for annual production [29]. As a result of high nutrient concentration in leaves compared to wood, the relative allocation of biomass to foliage influences the standing nutrient pools in a community. Nitrogen is reported to be the most common nutritional factor limiting photosynthesis and biomass production. The concentration of nutrient applied upto 588 mg of Nitrogen has resulted in about 3 times increase in nutrients. Nitrogen content in the leaves of *Phyllostachys pubescence* was found maximum the concentration of N subsequently increased crude protein content followed by K, P, Ca, Mg and inorganic constituents like ash with although there is significantly no change in biomass and associated parameters beyond 504 mg to 588 mg of nitrogen applied but foliar nutrient continue to increase beyond this concentration. Our results are in conformation with the study [30] who reported that relative growth rate continue to increase until foliar N concentration reaches its maximum. In a study higher fertilizer rate did not affect height and stem diameter although N concentration in shoots and leaves increased with increased N rate. It obviously appears that the internal nutrient reserves; which are necessary to develop quality planting material, are increased significantly by fertigating seedlings with desired levels of N. Our results are also in conformation with the results [31] which revealed that among the nutrients, percentage of nitrogen was highest in all the components followed by potassium and lowest in phosphorus in *Eucalyptus globulus.* Among the components leaves had highest concentration of nitrogen (1.3%), potassium (0.7%) and phosphours (0.08%) whereas wood had the lowest percentage of N, P and K. The study [32] on the effect of different Ca levels on cation concentration in leaves and fruit of apple trees revealed the synergistic effect of N and P on Ca and Mg in leaves and fruits of apple trees. A study [33] on the influence of Nitrogen and fruit load on the mineral contents of apple leaves reported synergistic effect of N and P on Ca and Mg in mineral content of apple leaves. The fertilization in giant bamboo of *Phyllostachys pubescens* on at Mount Jinyun, Chongqing, China, with NPK significantly increased the concentrations of N and P in leaves and subsequently increased the number of emerging new shoots [19]. Reducing N fertilization brings about a dramatic response in grass crude protein content of grasses and sometimes even leading to a two-fold decrease in values [34]. The increase in crude protein and ash content of maize with different combination of NP fertilizer over control and as such got minimum values in control according to them the increase in crude protein content due to increase in N concentration may be due to the reason that nitrogen application have enhanced amino acid formation [35]. The increasing level of N fertilizer resulted in significant ($P<0.01$) increase in the total CP yield up to 80 kg/ha but further increase of N (120 and 160 kg N/ha) fertilizer did not show any significant improvement of CP yield when compare with control and 40 kg N/ha [23, 33].

Conclusion

The nitrogen N use efficiency *i.e*. “the amount of N utilized by the plant to produce a unit of biomass” was decreased proportionately with increase in the content of N used for fertigating the seedlings. The minimum N use efficiency of

181.768 was recorded in seedlings fertigated with 21mg N seedling^{-1} week^{-1}. This value was around 3.13 times higher for seedlings raised under 3mg N seedling^{-1} week^{-1}. Seedlings fertigated with 21mg N seedling^{-1} week^{-1} recorded maximum *i.e.* about three times more nutrient content in the leaves viz. 2.98% nitrogen, 1.57% phosphorus, 1.70% potassium, 0.32% calcium, 0.21% magnesium, 18.53% crude protein and 2.483% ash content as compared to control, although at par with nutrient contents found in the leaves of seedlings fertigated with 18 mg of N seedling^{-1} week^{-1}.

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