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BIOMASS ALLOCATION AND UPTAKE EFFICIENCIES OF NITROGEN, PHOSPHORUS AND POTASSIUM BY *CRYPTOMERIA JAPONICA* (L.F.) D. DON VIS-À-VIS NITROGEN FERTIGATION

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ABSTRACT
Cryptomeria japonica seeds were sown in polybags (10 x 15 cm) with sterilized riverbed sand in first week of February 2012. Three to five seeds were sown in each polybag. Germinated seeds were thinned out to one seedling polybag^{-1} after 3 weeks of their emergence and then treated weekly with ingestad pretreatment nutrient solution for 4 weeks. Pretreated seedlings were fertigated with the following nitrogen levels 0, 3.00, 6.00, 9.00, 12.00, 15.00, 18.00 and 21.00 mg dissolved in 25 mL of water along with fixed levels of P, K, Ca and Mg seedling^{-1} week^{-1} up to 28 weeks as recommended by Ingestad and Lund (1979). Biomass allocation increased significantly both in shoots and roots with the increase in level of nitrogen fertigation and seedling age. With 21 and 18 mg seedling^{-1} of nitrogen fertigation, average shoot and rot dry weight increased about 3.8 and 3.0 times, respectively after 28 weeks compared to control but the effect of both treatment levels remained at par. Nitrogen, phosphorus and potassium content increased significantly with increase in nitrogen fertigation levels by 118%, 127.6% and 67.74%, respectively over control. Nitrogen, phosphorus and potassium uptake efficiencies first decreased followed by gradual increase with the increase in nitrogen fertigation level up to 21 mg seedling^{-1}. Contrary to this NUE, PUE and KUE decreased with increasing nitrogen fertigation level up to 21 mg seedling^{-1}.

INTRODUCTION

Cryptomeria japonica (L.f) D. Don, a coniferous evergreen indigenous to Japan and Southern China is widely used timber species in the Orient. Later it was introduced to the Darjeeling hills in the year 1862 from China (Luna, 2005). From Darjeeling it was later introduced to Kashmir valley. This plant does best in a fertile, deep, acidic, moist soil but will tolerate clay both during dry and wet periods. It is a tall tree with drooping branches, pyramidal crown and straight trunk attaining a height up to 50 m and girth 8m. Bark reddish-brown, fibrous peeling off in long strips. Needles deep green, awl-shaped quadrangular, 1-2 cm arranged spirally in five rows, flowers monoecious (Luna, 2005).

Under Kashmir conditions, the cones ripen in July to August and somewhat later at higher elevations and immediately after ripening, these cones open on tree itself, thus dispersing the seeds, leaving empty cones on trees, making seed collection difficult. Wood of Japan tree (*Cryptomeria japonica*) is dense, heavier and used for house-building, ship-building, bridges, furniture, boxes, tubs etc. Japanese extract an essential oil, called Sugi oil or Japanese cedar wood oil (Luna, 2005).

Fertigation has proved its superiority over conventional method of fertilizer application to ensure the right amounts of irrigation water and plant nutrients available at the root zone and nourish the crop requirements for stabilizing yield and quality of produce (Sharma *et al*., 2013). Fertigation also increases the nutrient use efficiency of crop by permitting timely application of fertilizers in small quantities in the vicinity of root zone matching with the plants' nutrient need, besides substantial saving in fertilizer usage and reducing nutrient losses (Singh *et al*., 2013). Not only this, fertilization accelerates shoot and root growth of plants, modify tissue nutrient contents and hence the amount of available reserves, improve post-transplant rooting, growth capacity, increase resistance to water stress, low temperature and disease (Shaw *et al*., 1998). These properties are of vital importance for successful plant establishment under unfavorable conditions (Birchler *et al*., 1998). Providing proper mineral nutrition to seedlings in nurseries is essential for optimum performance after out planting (Bigg and Schalau, 1990). Studying the efficient use of fertilizers to achieve maximum growth can economize production by decreasing fertilizer input and their run off. It is generally recognized that effective fertilizer management includes nutrient applications appropriate to various stages of plant growth. Since young seedlings are sensitive to high fertilizer concentrations, water soluble fertilizers are generally diluted to half the strength of recommended concentration during the first 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 (Marschner, 1995). Davidson *et al.* (1994) states that the common fertigation programs for linear production of woody plants include least amount of N applied in combinations with other soluble fertilizers. Fertigation often provides actual N requirements and thus more frequent doses accompanied with tissue analysis to determine concentrations needed for optimum growth (Kumar *et al.,* 2007). With this background the present study was taken to observe the effect of nitrogen fertigation on biomass accumulation, nutrient uptake efficiencies and their use efficiencies.

MATERIALS AND METHODS

A field experiment was conducted during the year 2012 at Faculty of Forestry, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir (SKUAST-K), Wadura, located at 34º172 N latitude and 74º332 E longitude at 1524 meter above mean sea level. The climate of the experimental site is temperate with mild summers and cold winters with wide variation in mean maximum and minimum temperature. The average precipitation of the study site is 170 mm mostly in the form of snow during winter months. The experiment was laid out in completely randomized design (CRD) with nine treatments of nitrogen fertigation (Table 1) and replicated thrice.

Experimental details

Germination of *Cryptomeria japonica* seeds was undertaken in the mist chamber at Faculty of Forestry, Wadura. Seeds (3-5) were sown in polythene bags (10 x 15cm) filled with sterilized common river bed sand and kept in mist chamber for germination in the first week of February, 2012. Germinated seeds were thinned out to one plant polybag^{-1} after 3 weeks of their emergence. Weeding was carried out manually as and when required. Polybags were irrigated once in a week when the fertilizer was not applied. The entire germinated seedlings were then fertigated at weekly intervals with ingestad pre-treatment nutrient solution (Ingestad and Lund, 1979) that included all major nutrients with weight proportions of N, P, K Ca and Mg as 100:13:65:7:8.5 @ 25mL seedling^{-1}for one month as pre-treatment. Each application supplied 3.00 mg N, 0.39 mg P, 1.95 mg K, 0.21 mg Ca and 0.25 mg Mg seedling^{-1}.

Table 1: Treatment Details of the experiment

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

Values in parentheses are concentration of nutrients in mg.

The pre-treated seedlings were shifted from mist chamber to nursery and treated weekly with nitrogen fertigation and continued for seven months (end of experiment). 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}. Nutrient fertigation was applied weekly @ 50mL seedling^{-1}. Control was also maintained and applied with plain water. The experimental details are given in Table 1. Nine seedlings from each treatment were selected randomly and pricked out at four week intervals to measure dry weight of root and shoot. The total nitrogen, phosphorus and potassium (Jackson, 1973) was measured by analyzing the same samples. Nitrogen, Phosphorus and Potassium uptake efficiency was determined as per procedure of Burgess (1991). NUE was estimated by dividing the amount of biomass of seedling at the end of growing season by the amount of nitrogen taken up by seedling during this period (Prescott *et al.*, 1989). Finally the data was subjected to the statistical analysis following the standard procedures. The variation between various factors and their interaction were tested at 0.05 per cent level of significance as followed by Gomez and Gomez (1984). The statistical analysis of data was carried out using the software OPSTAT.

RESULTS AND DISCUSSION

Biomass allocation pattern

The increase in nitrogen fertigation level from 0 to 21 mg seedling^{-1} led to increase in allocation of carbohydrates in shoots as well as roots of *Cryptomeria japonica* seedlings. As the total N addition increased from 96-600 mg seedling^{-1} up to 28 weeks, average shoot dry weight increased about 3.8 times, the highest dry weight being recorded at T_8 which remained at par to T_7 (Table 2). Similarly the highest root dry weight was

Table 2: Effect of nitrogen-fertigation on biomass allocation(g) to shoots of *Cryptomeria japonica* seedlings

N levels (mg seedling^{-1})	Age in weeks							Mean
	4	8	12	16	20	24	28	
$T_{0 = (0.00)}$	0.011	0.029	0.042	0.185	0.361	0.797	0.892	0.332
$T_{1 = (0.00)}$	0.014	0.044	0.049	0.190	0.378	0.842	0.933	0.350
$T_{2 = (3.00)}$	0.018	0.062	0.074	0.403	0.442	0.981	1.124	0.445
$T_{3 = (6.00)}$	0.029	0.097	0.077	0.491	0.555	1.097	1.150	0.501
$T_{4 = (9.00)}$	0.064	0.155	0.183	0.505	0.653	1.037	1.498	0.585
$T_{5 = (12.00)}$	0.091	0.184	0.294	0.644	0.719	1.571	1.720	0.746
$T_{6 = (15.00)}$	0.214	0.236	0.392	0.784	0.856	2.852	2.207	1.078
$T_{7 = (18.00)}$	0.337	0.551	0.575	1.021	1.121	2.559	2.662	1.261
$T_{8 = (21.00)}$	0.335	0.549	0.599	0.998	1.081	2.569	2.734	1.265
Mean	0.125	0.213	0.254	0.580	0.685	1.589	1.658	

C.D ($p \leq 0.05$); Treatment: 0.019; Age (weeks):0.017; Treatment × age - 0.051

Table 3: Effect of nitrogen-fertigation on biomass allocation (g) to roots of *Cryptomeria japonica* seedlings

N levels (mg seedling^{-1})	Age in weeks							Mean
	4	8	12	16	20	24	28	
$T_{0 = (0.00)}$	0.008	0.031	0.141	0.0281	0.256	0.456	0.660	0.226
$T_{1 = (0.00)}$	0.011	0.039	0.058	0.156	0.313	0.459	0.750	0.255
$T_{2 = (3.00)}$	0.024	0.062	0.072	0.327	0.358	0.649	0.783	0.325
$T_{3 = (6.00)}$	0.051	0.070	0.073	0.450	0.481	0.657	0.794	0.368
$T_{4 = (9.00)}$	0.117	0.081	0.173	0.470	0.602	0.744	0.864	0.436
$T_{5 = (12.00)}$	0.153	0.108	0.263	0.588	0.657	0.749	0.895	0.488
$T_{6 = (15.00)}$	0.180	0.231	0.362	0.688	0.702	0.756	0.956	0.554
$T_{7 = (18.00)}$	0.229	0.361	0.645	0.701	0.739	0.954	1.167	0.685
$T_{8 = (21.00)}$	0.230	0347	0.663	0.702	0.776	0.952	1.123	0.684
Mean	0.112	0.148	0.272	0.446	0.544	0.708	0.889	

C.D ($p \leq 0.05$); Treatment: 0.022; Age (weeks):0.019; Treatment $\times$ age - 0.059

recorded in T_7, the increase of which was about 3.0 times as compared to control. However by increasing the nitrogen to T_8 level, root dry mass decreased but remained at par to T_7 (Table 3). The effect of age on different components of seedling (shoot and root) biomass was conspicuous with highest (1.658 and 0.889 g) observed at 28 week which were 13.2 and 7.9 times more than the seedling shoot and root biomass at 4 week, respectively. With increase in age from 4 to 28 weeks, the biomass showed significant increase. Interaction between fertigation and seedling age of *Cryptomeria* japonica showed maximum shoot biomass of 2.734g with T_8 fertigation level at 28 week. However maximum root biomass (1.167g) was obtained with T_7 nitrogen fertigation level at 28 week. These findings are in agreement with the Brouwer (1966) who ascribes it to the fact that root meristems are closer to nutrient supply and receive disproportionate share of nutrients and consequently grow more rapidly than shoot meristems until the nutrient-carbohydrate ratio increases to the point where carbohydrates become more limiting to growth. Moreover, Ledig (1983) suggested that under high nitrogen condition plants allocate relatively more biomass to shoots and may grow faster by inverting a high proportion of their photosynthetic capital to shoots. The shift in relative total plant dry weight from the roots to the shoots might be due to redirection of the relative proportion of total plant N from the root system to leaves (Grime, 1979; Rose and Biernacka, 1999). Li *et al*. (1991) reported that nitrogen had significant effects on seedling growth and biomass allocation to needles, stem and roots. Low N results in smaller size seedlings as relatively more biomass was allocated to roots than under high N conditions. Similar sort of findings has also been reported by Ahmad *et al*. (2013) in *Pinus Wallichiana*.

Effect of nitrogen fertigation on nutrient content and their uptake efficiencies

The present study revealed a marked increase in the content of nitrogen, phosphorus and potassium (Fig. 1) in *Cryptomeria japonica* seedlings with increase in nitrogen fertigation level. Increase in the nitrogen fertigation up to 21 mg seedling^{-1} enhanced mean nitrogen from 11.10 to 24.20 mg. With increase in the nitrogen fertigation level, the increase in nitrogen content in the plant is inevitable. Phosphorus content increased from 1.41 to 3.21 mg by increasing the nitrogen fertigation level from T_0 to T_8. Moreover potassium content in the seedling increased from 7.75 to 13.0 mg by increasing the nitrogen fertigation from T_0 to T_8 level. The uptake of these nutrients rather the mineral mass also followed the similar trend (Fig. 2) as the uptake is the product of dry matter and respective nutrient contents. Moreover, dry matter (Fig. 3) also increased from 1592 to 3899 by increasing the nitrogen fertigation level from T_0 to T_7 hence uptake of nutrients also increased. Nitrogen fertilization improves the nutritional environment both in the rhizosphere and plant system. The increased availability of the nutrients in the root zone coupled with increased metabolic activity may have increased the phosphorus and potassium absorption, accumulation and uptake subsequently (Ganie *et al*., 2014).

As the nitrogen fertigation level increased from T_0 to T_8, the nitrogen uptake efficiency first increased up to T_1 and then decreased abruptly up to T_2 from where it decreases gradually up to the T_8 level. Nitrogen uptake efficiency decreased from 113.3 to 4.03% (Fig. 1) by increasing nitrogen from T_1 to T_8 level. With increase in nitrogen level, nitrogen content also increases. But the increase in the nitrogen content is less as compared to that of nitrogen applied, moreover, nitrogen uptake efficiency is the ratio of nitrogen content and nitrogen applied hence the nitrogen use efficiency decreases. These results are in agreement with that of Burgess (1991) who observed nitrogen uptake efficiency of 30.60 and 22.42 % at highest (6% addition) rate in Douglas fir and Western hemlock, respectively. Burgess (1991) further reported that although both Douglas for and Western hemlock grew fastest under 6% nitrogen fertigation rate; Western hemlock was more efficient in nitrogen uptake. Contrary to these findings Jackson *et al*. (2007) observed increase in total nitrogen content seedling^{-1} of long leaf pine with increase in nitrogen fertigation rate. Ahmad *et al*. (2013) also reported similar results in *Pinus wallichiana* seedlings. Phosphorus and potassium uptake efficiencies also follow more or less a similar trend (Fig. 1).

Effect of nitrogen fertigation on nutrient use efficiencies

As the nitrogen fertigation level increased from T_0 to T_8, the nitrogen use efficiency decreased. Nitrogen use efficiency (NUE) decreased from 132.6 to 6.45% (Fig. 3) by increasing nitrogen from T_1 to T_8 level. Nitrogen use efficiency (CO_2 of *Cryptomeria japonica* seedlings per unit of nitrogen absorbed from the medium) was lowest (6.45 %) at highest N addition rate of 21 mg of N seedling^{-1}. With increase in nitrogen level, dry matter also increases. But the increase in the dry matter is less as compared to that of nitrogen, moreover, nitrogen use

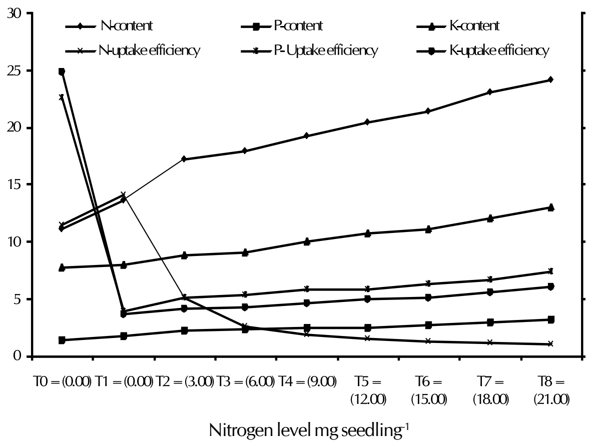

Figure 1: Effect of nitrogen fertigation on Nutrient content and their uptake efficiencies in *Cryptomeria japonica* seedlings

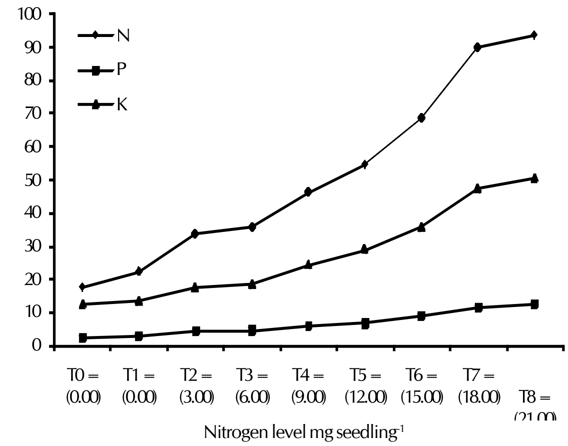

Figure 2: Effect of nitrogen fertigation on mineral mass (g/kg) in *Cryptomeria japonica* seedlings after seven months

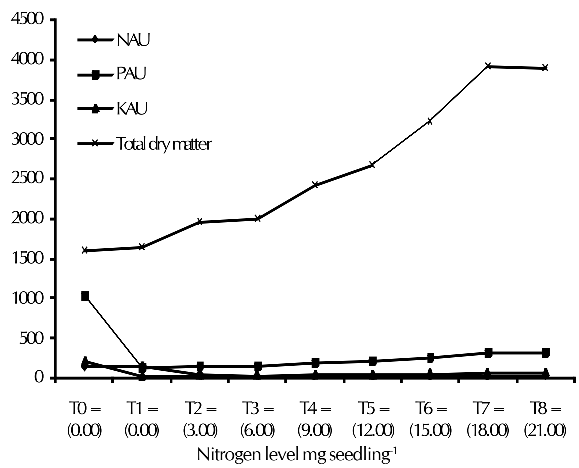

Figure 3: Effect of nitrogen fertigation on total dry matter and nutrient use efficiency in *Cryptomeria japonica* seedlings

efficiency is the ratio of total dry matter and nitrogen applied hence the nitrogen use efficiency decreases. Low NUE may be as a result of inefficient allocation of nitrogen among the photosynthetic compounds such that some compounds are present in excess while the rate limiting compounds are underrepresented. For example shade plants invert larger quantity of nitrogen in light harvesting pigments and proteins, bur make only small investment in RUBISCO and other CO_2 processing enzymes (Bjorkman, 1981; Evans, 1989). Our results are in line with that of Reich and Schoettle (1988) who reported that in white pine (*Pinus strobus*) seedlings NUE decreases with increase in concentration of nitrogen in tissues. Difference in NUE may also result from difference in allocation levels. Contrary to this, Masoodi *et al*. (2007) reported NUE of 57.47% in *C. deodara* and 100.14% in *Cupressus torrulosa* at 9 mg nitrogen addition rate. Unlike NUE, phosphorus and potassium use efficiency increases (Fig. 3) slightly with increase in nitrogen fertigation level. As we know that with increase in nitrogen level, dry matter increases which is slightly more as compared to that of phosphorus and potassium application which is constant, moreover, Phosphorus and Potassium use efficiency is the ratio of total dry matter and phosphorus and potassium applied, respectively hence there is slight increase in the use efficiencies of phosphorus and potassium.

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