Altitudinal variation in carbon sequestration potential of micropropagated *Dendrocalamus asper* in the mid Himalayan region of India

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Abstract

Bamboo is a are fast growing plant and in nature has a potential to increase the carbon stocks at a faster rate. Bamboo can be one of the potential species for plantation in the degraded or wastelands as a carbon sink. Bamboo also plays very important role in the livelihood improvement of rural population. Since; bamboo accumulates biomass quickly and offers the opportunity to maintain and increase carbon stocks through carbon sequestration; studies on carbon sequestration through bamboo plantation are of utmost importance to address the Clean Development Mechanism (CDM). A trial plantation of micropropagated *Dendrocalamus asper* was done at various altitudes (ranging from 900-1400 m a.s.l.) in the mid Himalayan region of India. Carbon sequestration was evaluated on the basis of above ground biomass produced. Above ground biomass and carbon sequestration in *D. asper* at five places varied from 18.55-121.70 kg plant^{-1} and 3.70 - 24.34 t ha^{-1}, respectively. Annual per cent increase in above ground biomass was 26.31, 11.23 and 51.28 in 3rd, 4th and 5th year, respectively at ARS, Majhera. Leaf Area Index of *D. asper* revealed an increasing trend from the month of March to November at ARS, Majhera. Maximum above ground biomass and carbon sequestration of *D. asper* was at 1000m a.s.l. in mid Himalayan region of Uttarakhand.

Introduction

The world's longest and highest mountains are Himalayas, which ranges over 2,500 km long and 400 km wide. This Himalayan range includes most of Nepal, Bhutan, south Tibet and the extreme north of India. Himalayan range is not only extremely sensitive to climate change but also has a great pressure on the forests in the rural areas for timber and fodder. India greatly depends on the Himalayan region for its forests reserves. In the hottest and driest outer Himalayas such as Siwalik Hills, a limited range of species such as *Dendrocalamus strictus*, *Bambusa bambos*, *Bambusa nutans* and *Dendrocalamus hamiltonii* occur. In the inner valleys of such areas due to water stress, bamboo distribution is severely limited. The genera *Himalayacalamus, Thamnocalamus and Yushania* are widely distributed in temperate forests. Unfortunately, this natural resource is depleting at an alarming rate due to degradation of natural habitat, forest fires, unscientific and illegal harvesting by the rural population along with insufficient plantation (Bakshi et al. 2012). The sustainable management of the bamboo resource is not only relevant to the tangible products of sustained shoot and culms harvest, but also for the sustained provision of important ecosystem services such as carbon sequestration, erosion containment and local climate regulation (Zhou et al. 2005). A series of field experiments on the silvicultural management of bamboo have been conducted in Australia and the Philippines (Midmore et al. 1998; Midmore and Kleinhenz 2000; Kleinhenz and Midmore 2001, 2002).

The issue of highest importance to developing countries is reducing the vulnerability of their natural and socio-economic systems to the projected climate change (Sathaye J et al. 2006). The Clean Development Mechanisms (CDM) is the only instrument that links developed countries to the reduction of emissions, and which could lead those countries to invest resources by sowing plantations with high potential to fix atmospheric carbon di oxide (Riano et al. 2002). Since, bamboo accumulates biomass quickly and offers the opportunity to maintain and increase carbon stocks through carbon sequestration; studies on carbon sequestration through bamboo plantation are of utmost importance to address the Clean Development Mechanism (CDM) to achieve the goal of climate convention. In India, some studies on biomass production in bamboo in the Himalayan region of Uttarakhand state have been conducted (Saxena et al. 2001; Agarwal and Purwar 2009, 2012). The aim of the present study was to evaluate the potential of micropropagated *D. asper* in above ground biomass production and carbon sequestration at various altitudes (900-1400m a.s.l.) in the mid Himalayan region of Uttarakhand.

Material and Methods

Plants of *D. asper* were produced at Agriculture Research Station, Majhera through micropropagation. Various places with varying altitudes were chosen for plantation of *D. asper* in the Nainital district of Uttarakhand. Plantation of micropropagated plants was done in the year 2006-07 at Research station, Majhera (1000m a.s.l.), Jarmila (900m a.s.l.), Jeolikote (1200m a.s.l.), Alchauna (1300m a.s.l.) and Mehra Gaon (1400m a.s.l.). Data on different growth parameters was recorded for the non destructive calculation of above ground biomass (on dry weight basis) followed by Agarwal & Purwar (2009). Length and girth of culms at 1.0m & 1.5m including the total number of culms was recorded 7 years after the plantation. In each clump data of three culms was used for the estimation of above ground biomass (kg Pole^{-1}). Total above ground biomass of the clump was obtained by multiplying the number of total culms to the average of biomass per pole. One plant was considered as one replication and three replications were maintained. Carbon sequestration was estimated on the basis of fifty per cent of the total above ground biomass produced (Scurlock et al. 2000; Singh et al. 2009).

Annual increment in the above ground biomass of micropropagated *D. asper* was recorded in the plantation done in the year 2009 at Research Station, Majhera. Growth parameter as mentioned above were recorded in the year 2011, 2012, 2013 & 2014 and above ground biomass was estimated. Leaf area index (LAI) was also measured using digital Plant Canopy Imager CI-110-24 PLB (CID. Inc, USA). Data on LAI was recorded at various time intervals in four years for the better understanding of pattern of plant growth in subsequent years.

Results and Discussion

Above ground biomass and the carbon sequestration potential of micropropagated *D. asper* at various altitudes in a growth period of seven years presented in Table 1. Highest production of above ground biomass (121.7 kg plant^{-1}) and carbon sequestration (24.34 t ha^{-1}) was recorded at Research Station, Majhera (1000m a.s.l.). The lowest potential of carbon sequestration (3.71t ha^{-1}) was recorded at Alchauna (1300m a.s.l.) among all the five places of study which was 84.75 per cent less than Majhera. However, per cent decrease in carbon sequestration was 62.7, 45.03 & 30.12 at Jarmila (900m a.s.l.), Jeolikote (1200 m a.s.l.) and Mehra gaon (1400m a.s.l.) respectively, as compared to Majhera. Kao and Chang (1989) reported the maximum net annual production (41.4 t ha $^{-1}$) during the 8th year in a *D. asper* plantation in Taiwan while in the present study it was only 24.34 t ha^{-1} after 7 year of plantation in mid Himalayan region. Low above ground biomass was recorded due to unmanaged plantation at all the five places. Kao and Chang (1989) also reported the effect on biomass is marked. For example, net annual biomass production of 9.3 t ha^{-1} per year in 12-15 year old *D. asper* was raised to 26.3 t ha^{-1} per year, one year after the culms more than 4 years of age were removed from the clumps. Riano et al. (2002) used mathematical functions to describe the growth of *Guadua angustifolia* in Cauca river valley of Colombia. *G. angustifolia* is one of the 3 largest bamboo species and important in the world. For 400 clumps ha^{-1} of *G. angustifolia* carbon fixation estimation is reported 43.5 t to the aerial part of the clump in 6 years of growth period. In the present study, *D. asper* being the medium sized bamboo has performed in coherence with the reports available. Growth pattern of *D. asper* indicated that there was no correlation between the altitude and the maximum height attained or total number of culms produced (Figure 1). As per Midmore

(2009) biomass production is affected by the management of culms, if bamboo stands are left undisturbed, biomass production increases until aboveground and belowground competition results in decreasing annual rates of biomass gain. Maximum height was gained at 1000m whereas number of culms was at par at 1000 and 1200 m. At 1300 m altitude height of the culms and number of poles were minimum as a result produced minimum biomass.

Table1: Above ground biomass and carbon sequestration by *D. asper* at various altitudes

Place	Altitude in meter (a.s.l.)	On dry weight basis above ground biomass (kg plant^{-1})	Carbon sequestered (kg plant^{-1})	Carbon sequestered (t ha^{-1})
Jarmila	900	45.38	22.69	9.08
ARS, Majhera	1000	121.70	60.85	24.34
Jeolikote	1200	66.89	33.45	13.38
Alchauna	1300	18.55	9.37	3.71
Mehragaon	1400	85.04	42.52	17.00

About 112.65 per cent increase in the carbon sequestration from 2011 to 2014 was recorded in the plantation of micropropagated *D. asper* done at ARS, Majhera in 2009. Annual per cent increase in above ground biomass was 26.31, 11.23 and 51.28 in 3rd, 4th and 5th year, respectively (Table 2).

Annual growth pattern indicated that maximum height attained was almost double in three years (2011-2014) but there was no significant increase in number of culms produced at ARS, Majhera (Figure 2).

Table 2: Pattern of annual increment in above ground biomass of *D. asper* at ARS Majhera

Year	Above ground biomass (On dry weight basis) kg plant^{-1}	Annual Per cent increase in above ground biomass	Carbon sequestered kg plant^{-1}	Carbon sequestered t ha^{-1}
2011	11.06 ± 1.6	-	5.53	2.21
2012	13.97 ± 2.0	26.31	6.99	2.79
2013	15.54 ± 2.0	11.23	7.77	3.11
2014	23.51 ± 2.4	51.28	11.76	4.70

Leaf area index (LAI) is a dimensionless quantity that characterizes plant canopies. LAI is used to predict photosynthetic primary production as a reference tool for plant growth. Data on LAI of *D. asper* recorded at ARS, Majhera from Nov, 2011- Nov, 2014 revealed an increasing trend from the month of March to November at ARS, Majhera due to active period of growth of *D. asper* (Figure 3). In consecutive years of plantation, leaf area index in the month of November varied from 1.66 to 2.14.

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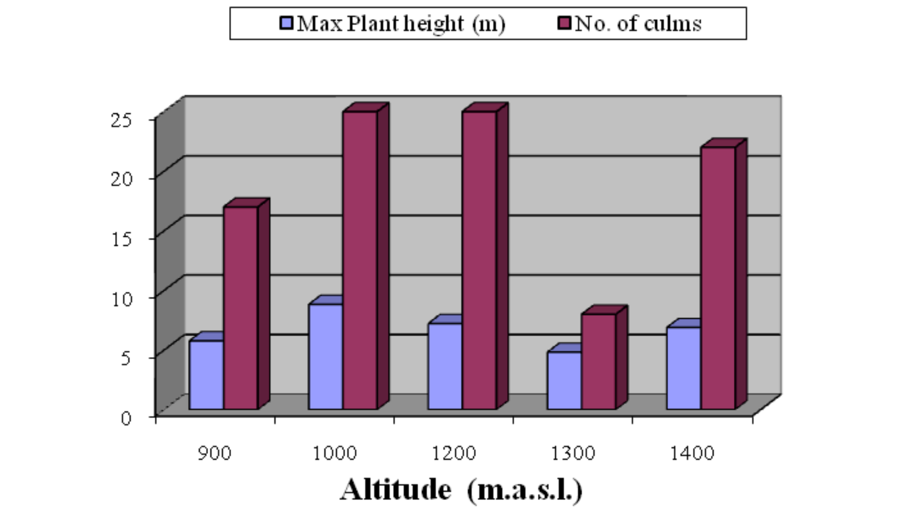

Figure 1: Growth pattern of micropropagated *D. asper* at various altitudes

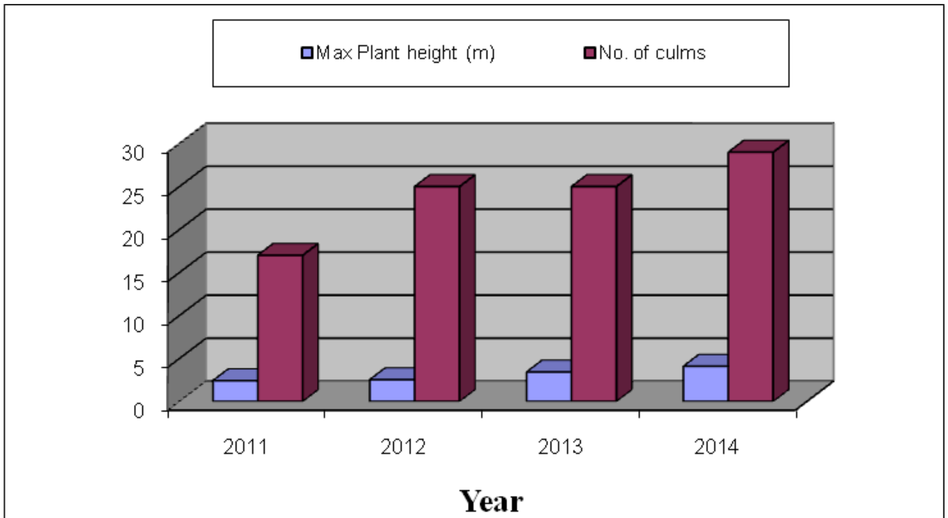

Figure 2: Growth pattern of micropropagated *D. asper* at ARS, Majhera

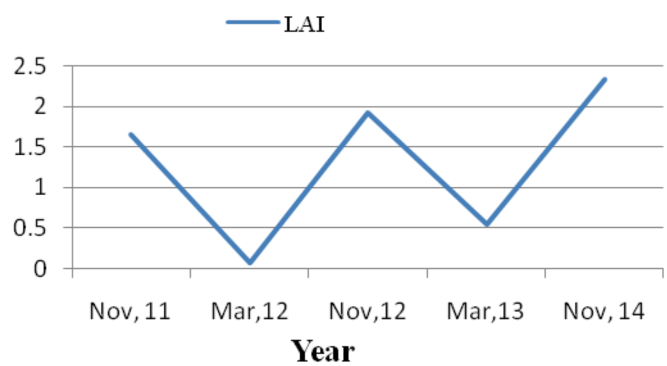

Figure 3: Leaf Area Index of *D. asper* at ARS, Majhera