Print : ISSN 0970-7662

Journal of Tree Sciences

online available at www.ists.in

Volume 33 No. 2 December, 2014

Accounting biomass and carbon dynamics in *Populus deltoides* plantation under varying density in *Tarai* of central Himalaya

B. Pingale, OPS Bana, A. Banga, S. Chaturvedi, R. Kaushal*, S. Tewari and Neema

*G.B. Pant University of Agriculture & Technology, Pantnagar, India; * Central Soil and Water Conservation Research and Training Institute, Dehra Dun*

ABSTRACT

In the present investigation biomass, carbon storage and carbon sequestration potential along different tree densities in *Populus deltoides* plantations were assessed in 8 years old plantation. The growth rate of diameter at breast height (DBH) and height was higher in trees at 200 to 250 trees ha^{-1} and 200 to 333 trees/ha years, respectively. The biomass and carbon stock increased with tree density and reached maximum at 1000 trees ha^{-1}. The contribution of stem was maximum compared to branch and litter in total biomass carbon. Soil organic carbon percentage showed a decreasing trend with increasing soil depth in the entire plantation whereas bulk density increased with increasing soil depth. SOC stocks increased with increase in density irrespective of soil depth. In the surface layer (0–15 cm), SOC stocks were 36.2 % higher at 1000 trees/ha. The carbon sequestration in biomass and soil increased with increasing the tree densities. Total Carbon sequestration by biomass + soil was maximum (142.9 t ha^{-1}) with 1000 trees ha^{-1} which was greater than other tree densities. Soil carbon stock contributed more to the total soil organic carbon as compared to the above ground biomass. This study recommends *P. deltoides* planting as a viable option for sustainable production and carbon mitigation.

Key words:

Biomass, carbon sequestration, carbon stocks, growth, Populus deltoides

INTRODUCTION

Agroforestry tree species are an important terrestrial means of capturing and storing atmospheric carbon in vegetation, soil and biomass products. The United Nations Framework Convention on Climate Change recognized plantation forestry as one of the mitigation option, as well as the need to monitor, preserve and enhance terrestrial carbon stocks (Updegraff et al. 2004). Due to fast growth and better silvicultural practices and management, Agrisilviculture has an edge over natural plantations. Poplar (*Populus deltoides* W.Bartram ex Marshall) has received wide acceptance during the last few decades in India. Due to its fast growing habit, deciduous nature, multipurpose use its compatibility with agriculture crops, and high industrial requirements, the species is widely grown in Indo-Gangetic region of the country. An area of 312,000 ha is planted with *P. deltoides* in the country, out of which 60% is block plantation and 40% is bund plantation (ICFRE 2012). The tree is harvested at a short rotation of 7–10 years, which provides a yield of 150–200 m^3 ha^{-1} in block plantations and 12–20

m^3 ha^{-1} in boundary plantations (Kishwan and Kumar 2013). Due to its fast growth and wider adoptability, the tree has huge potential to sequester carbon and mitigate CO_2 from the atmosphere (Chauhan et al. 2010; Gera 2012). Comprehensive reports on biomass, productivity, structure, and functioning of *P. deltoides* plantations are available in the literature from India (Das and Chaturvedi 2005). However, information pertaining to biomass, carbon stocks, and sequestration rates of plantations under varying density are scanty. The present study was therefore designed to estimate growth and biomass production, carbon capture potential and its distribution in the different pools (biomass and soil) for *P. deltoides* along different tree density to find out most suitable substitution of components for maximum carbon sequestration .

MATERIAL AND METHODS

The study was conducted in the Plantation of *P. deltoides* Bartr. ex. Marsh. of G-48 clone raised in February, 2000 at old site of Agroforestry Research Centre (AFRC), Patharchatta, G.B. Pant University of Agriculture & Technology, Pantnagar Uttarakhand, India. The experiment consisted of six treatments i.e. tree densities (1000, 500, 333, 250, 200 and zero trees ha^{-1}) each containing 16 tress/plot. The field experiment was laid out in randomised complete block design with six treatments i.e. tree densities (1000, 500, 333, 250, 200 and zero trees ha^{-1}) and four replications under mixed agrisilvicultural system to study the relative efficiency of above and below ground carbon sequestration, to work out the relative contribution of soil organic carbon stock under poplar based agroforestry system with varying tree density and thereby to find out most suitable substitution of components for maximum carbon sequestration. All the 16 trees were measured for their diameter at breast height (DBH) and height with tree caliper and Ravi's altimeter, respectively. To measure the aboveground biomass the tree was divided into following sub-groups viz., stem, branch and litter. Subsamples of different components were ground in a wiley mill. A total of 50% of the ash-free mass was taken as the carbon content. The ash content was determined by igniting 1 g of powdered sample at 550°C for 6 h in a muffle furnace (Allen 1989).

To estimate total soil organic carbon stock soil samples were randomly collected at 3 different places at 3 depths (0–15, 15-30, and 30-45 cm) from each tree density. The samples were mixed to obtain a composite sample for each depth Soil samples were analyzed for soil organic carbon (SOC) by the Walkley and Black (1934) method. Bulk density was determined using metal core samplers of 4.0 cm in height and 5.0 cm in internal diameter at 3 depths (0–15, 15-30, and 30-45 cm) . Samples were then oven-dried separately at 105 ± 10 °C for 48 h. The oven-dried weight of the sample divided by the volume of core sampler gave the bulk density of soil. The amount of carbon stored per hectare was obtained by multiplying the values of soil depth (cm), bulk density (g cm^{-3}), and the percentage of SOC content (Joa Carlos et al. 2001).

Statistical analysis

The data on growth, AGB, soil carbon, and bulk density were analyzed after one-way analysis of variance (ANOVA) using SAS 9.3 statistical software. Significant differences were tested at $P \leq 0.05$ using Tukey's least significant difference test.

RESULTS AND DISCUSSION

Growth parameters and biomass carbon stocks

Tree growth parameters revealed that with increase in tree density a gradual decrease in DBH was observed with maximum DBH (32.4 cm) at 200 trees ha^{-1} (Fig. 1). The incremental rate of DBH was higher between 200-250 (trees ha^{-1}) tree density, after which mean DBH and Height (m) of poplar tree as influenced by varying tree density the rate of increase was slow. Height of the trees was not influenced significantly due to varying poplar tree density and it ranged from 20.15m under 1000 trees ha^{-1} to 21.83 m under 333 trees ha^{-1}. Mean carbon content (%) in aboveground components varied from 46 .2 % to 47.0 % (Table 1). The maximum carbon concentration was observed in litter (47.0%) followed by branch wood (46.2%) and stem (46.2%).

The biomass and carbon stock increased with tree density and reached maximum at 1000 trees ha^{-1} (Table 2). Total biomass increased from 63.36 t ha^{-1} at 200 trees ha^{-1} to 147.26 t ha^{-1} at 1000 trees ha^{-1}. The contribution of stem to the total

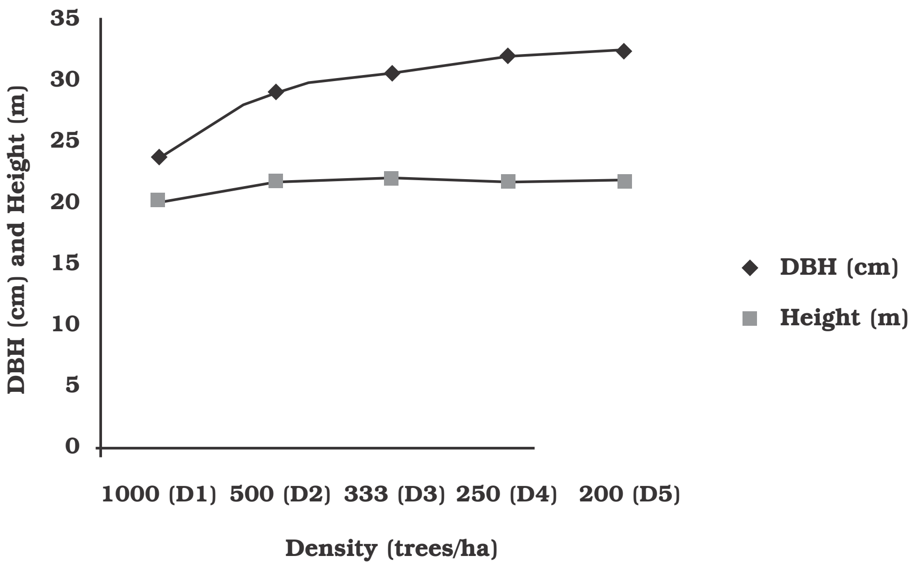

Fig. 1. Mean DBH and Height(m) of poplar tree as influenced by varying tree density

Table 1: Mean Carbon (%) in different components of *P. deltoides.*

Tree Parts	% Carbon
Stem-wood	46.2
Branch-wood	46.2
Litter	47.0

Table 2: Estimated biomass and carbon stocks in the *P. deltoides* plantation by tree density

Tree density	Biomass (t/ha)				Above ground carbon stock (t/ha)			
(trees/ha)	Stem	Branch	Litter	Total	Stem	Branch	Litter	Total
1000 (D1)	130.05	15.31	1.9	147.26	60.08	7.08	1.87	71.89
500 (D2)	95.26	12.50	1.3	109.06	44.01	5.78	1.44	54.26
333 (D3)	68.23	10.11	1.1	79.44	31.53	4.67	1.14	40.43
250 (D4)	53.16	9.06	1.0	63.22	25.00	4.18	1.04	33.34
200 (D5)	45.53	8.13	9.7	63.36	21.03	3.75	0.98	29.07
Control (D6)	-	-	-	-	-	-	-	3.58
SEm ±	5.33	0.76	0.06	-	2.51	0.35	0.06	-
CD at 5%	16.42	2.35	0.2	-	7.74	1.07	0.19	0

biomass was maximum and varied from 45.53 to 130.05 t ha^{-1}. The stem biomass (t ha^{-1}) was higher under closest spacing 1000 trees ha^{-1} which reduced with increased tree density and lowest stem biomass observed under the sparse density 200 trees ha^{-1} (Table 2). However the differences between 333 and 250 trees ha^{-1} was not significant. The results are in accordance with the findings of Bhardwaj (2001) under the high density poplar plantation. Aboveground carbon stocks in *P. deltoides* increased from 29.07 t ha^{-1} at 200 trees ha^{-1} to 71.89 t ha^{-1} at 1000 trees ha^{-1} (Table 2). The contribution of stem was maximum compared to branch and litter in total biomass carbon. In general, contributions by stem, branch, and litter to the total carbon stocks increased with the advancement of tree density from 200 to 1000 trees ha^{-1}.

Table 3: Soil organic carbon percentage (%) at different soil depths as influenced by varying tree density

Tree density (trees/ha) (A)	Soil depth 0-15cm	15-30cm	30-45cm	Mean
1000 (D1)	1.91	1.04	0.73	1.23
500 (D2)	1.83	1.02	0.66	1.17
333 (D3)	1.80	0.94	0.66	1.13
250 (D4)	1.51	0.85	0.56	0.98
200 (D5)	1.44	0.87	0.50	0.93
Control (D6)	1.07	0.82	0.47	0.80
Mean	1.59	0.92	0.58	-

	SEm(±)	CD (5%)	CV(%)
For A	0.03	0.06	
For B	0.02	0.05	8.04
For two B at same level of A	0.06	0.16	
For two A at same or different level of B	0.06	0.15	

Table 4: Soil bulk density (g cm^{-3}) upto different soil depths as influenced by varying tree density

Tree density (trees/ha) (A)	Soil depth 0-15cm	15-30cm	30-45cm	Mean
1000 (D1)	1.26	1.32	1.31	1.30
500 (D2)	1.27	1.33	1.32	1.31
333 (D3)	1.28	1.34	1.32	1.32
250 (D4)	1.29	1.37	1.33	1.33
200 (D5)	1.29	1.38	1.33	1.33
Control (D6)	1.32	1.44	1.36	1.37
Mean	1.29	1.36	1.32	-

	SEm(±)	CD (5%)	CV(%)
For A	0.004	0.008	
For B	0.002	0.005	3.78
For two B at same level of A	0.006	0.012	
For two A at same or different level of	0.006	0.013	

Table 5: Total soil organic carbon stock (t ha^{-1}) upto different soil depths as influenced by varying tree density

Tree density (trees/ha) (A)	Soil depth 0-15cm	15-30cm	30-45cm	Mean
1000 (D1)	36.16	20.51	14.34	23.67
500 (D2)	34.92	20.41	13.10	22.81
333 (D3)	34.67	18.87	13.10	22.21
250 (D4)	29.17	17.40	11.14	19.24
200 (D5)	27.78	18.04	10.20	18.39
Control (D6)	21.19	17.71	9.25	16.37
Mean	30.65	18.82	11.87	-

	SEm(±)	CD (5%)	CV(%)
For A	0.57	1.21	
For B	0.48	0.98	8.18
For two B at same level of A	1.18	2.39	
For two A at same or different level of B	1.12	2.30	

Table 6. Total carbon stocks in different ages among the *P. deltoides* plantation.

Tree density (trees/ha)	Carbon stock (t/ha)		
	Above ground	Soil organic carbon	Total
1000 (D1)	71.89	71.01	142.9
500 (D2)	54.26	68.42	122.68
333 (D3)	40.43	66.63	107.06
250 (D4)	33.34	57.72	91.06
200 (D5)	29.07	55.16	84.23
Control (D6)	3.58	49.10	52.68
SEm±	2.63	1.18	-
Cd at 5 %	7.95	3.56	-

Soil carbon

The difference in SOC due to age was significant (Table 3). Soil organic carbon percentage showed a decreasing trend with increasing soil depth in the entire plantation. In surface soil (0-15 cm), SOC was 1.91% higher in the 1000 trees ha^{-1} plantation than in the 200 trees ha^{-1}. John (2004) also reported decreasing trend of SOC (%) successively from surface to subsurface soil. The SOC stock (t ha^{-1}) was observed to decrease significantly with increasing the soil depth and the upper soil layer (i.e. upto 15 cm) showed maximum and significantly higher SOC stock (t ha^{-1}) followed by middle (15-30 cm) soil depth and deeper 30-45 cm soil depth under all the tree densities. These results are similar and well supported by the findings of Smith and Heath (2002) and Sharma (2004).Bulk density increased with an increase in soil depth at all the densities (Table 4). Bulk density showed a decreasing trend with an increase in the density of the trees. In surface soil, it decreased from 1.288 t ha^{-1} at 250 trees ha^{-1} to 1.262 at 1000 trees ha^{-1}. Bulk density reduced with increase in both in SOC (%). Such inverse relationship of the bulk density and SOC was also reported by Gupta and Sharma (2008) and Singh et al. (2004). Total soil organic carbon stock varied due to different densities of trees (Table 5). SOC stocks increased with increase in density irrespective of soil depth. In the surface layer (0–15 cm), SOC stocks were 36.16 % higher at 1000 trees ha^{-1}. Not many variations were observed in the subsurface soil layer (at 15–30 and 30–45 cm depth). The mean soil organic carbon stock was maximum in 1000 tree ha^{-1} while minimum was with the control plots.

Total carbon stocks

The carbon sequestration in biomass and soil increased with increasing the tree densities (Table 6) Total Carbon sequestration by biomass + soil was maximum (142.9 t ha^{-1}) with 1000 trees ha^{-1} which was greater than other tree densities. The amount of total carbon (biomass and soil) increased from 52.68 at control plots to 142.9 at 1000 trees ha^{-1}. Carbon stock from the vegetation became almost equivalent to SOC stock at the density of 333 to 1000 trees ha^{-1}. Soil carbon stock contributed more to the total soil organic carbon as compared to the above ground biomass. Soil organic carbon sequestration was maximum (71.01 t ha^{-1}) and significantly higher under 1000 trees/ha than all other densities, except 500 trees ha^{-1}. Similar results were reported by Arora et al. (2014) for *P. deltoides*.

REFERENCES

Allen SE, Grimshaw HW, Parkinson JA, Quarnby C 1989 Chemical analysis of ecological materials. Oxford: Blackwell Scientific Publications

Arora G, Chaturvedi S, Kausal, R, Tewari SK and Chaturvedi OP 2012 Growth, Biomass, Carbon Stocks and Sequestration in Age Series *Poplus deldoides* Plantations. *Turkish Journal of Agriculture and Forestry* **38:** 550-560.

Bhardwaj SD, Panwar P and Gautam S 2001 Biomass production potential and nutrient dynamics of *Populus deltoides* under high density plantations. *Indian Forester* **121(2):** 144-153.

Chauhan SK, Sharma SC, Beri V, Ritu, Yadav S, Gupta N 2010 Accounting poplar and wheat productivity for carbon sequestration agri-silvicultural system. *Indian Forester* **136:** 1174– 1182.

Das DK and Chaturvedi OP 2005 Structure and function of *Populus deltoides* agroforestry systems in eastern India: 1. Dry matter dynamics. *Agroforest System* **65:** 215–221.

Gera M, Mohan G, Bisht, N.S. and Gera N 2012 Carbon sequestration potential of agroforestry under CDM in Punjab state of India.*Indian J. For* **34:** 1–10.

Gupta MK and Sharma SD 2008 Effect of tree plantation on soil properties, profile morphology and productivity index in Uttarakhand. *Annals of Forestry.* **16(2):** 209-224.

ICFRE 2012 Country Report on *Poplars* and *Willows*. Dehradun,India: Indian Council of Forestry Research and Education.

John PA 2004 Evaluation of sustainable production of wheat yield in rice-wheat cropping system. M.Sc. Thesis, G.B. Pant University of Agriculture and Technology, Pantnagar, India.

Joa Carlos de MS, Carlos CC, Warren AD, Lal R, Filho SPV, Piccolo MC and Feigl BE 2001 Organic matter dynamics and carbon sequestration rates for a tillage chronosequence in a Brazilian Oxisol. *Soil Sci Soc of Am J* **65:** 1486–1499.

Kishwan J and Kumar D 2013 Future of Poplars in India. Rome, Italy: Food and Agricultural Organization of the United Nations. Available online at http://www.fao.org/forestry/6285-037bdb32f78ab8a552bf6b163f2ffc825.pdf.

Singh G, Rathod TR and Chouhan S 2004 Growth biomass production and associated changes in soil properties in *Acacia tortolis* plantation in relation to stand density in Indian arid zone. *Indian Forester*. **23:** 605-613.

Smith JE and Heath LS 2002 A model of forest floor carbon mass of United States type. Research paper NE-722, Newton Square, PA: USDA Forest Service.

Sharma M 2004 Long term effect of fertilizers and manure on some physical properties of soil and nutrient uptake by wheat. M.Sc. Thesis. G.B. Pant University of Agriculture and Technology, Pantnagar, India.

Updegraff K, Baughman MJ and Taff SJ 2004. Environmental benefits of cropland conversion to hybrid poplar: economic and policy considerations. *Biomass Bioenergy* **27:** 411–428.

Walkley AJ and Black IA 1934 An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Science* **37:** 29–38.