Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2018; 7(3): 2968-2971
Received: 15-03-2018
Accepted: 20-04-2018

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Effect of different spacing geometries of *Populus deltoides* on carbon sequestration potential of poplar based agroforestry system in North-Western Haryana

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Abstract
The present study was carried out in poplar planted with different spacing *i.e.* 5x4 m, 10x2 m and 18x2x2 m at CCS Haryana Agricultural University, Hisar for the assessment of carbon sequestration potential of poplar based agroforestry system. It was observed that the height and GBH increased considerably with the advancement of age of poplar under different spacings. After 8 years of transplantation, height was not influenced by different spacings of poplar whereas the girth varied significantly in different spacings and less girth was recorded in paired row geometry (18x2x2m). The soil under poplar based agroforestry system showed 39.7 per cent more organic carbon than sole crop. The soils under poplar based agroforestry had 2.9–4.4 Mg ha^{-1} higher soil organic carbon than in sole crop. Mean rate of carbon storage has been found higher in agroforestry than in sole crop. The mean rate of carbon storage in agroforestry has been found to be 113 per cent higher than sole Agriculture. The rate of carbon storage was found to be 25.2 t/ha/year in poplar based agroforestry system and 11.8 t/ha/year in sole agriculture.

Keywords: *Populus deltoides*, carbon sequestration, agroforestry system, spacing

Introduction
Populus, one of the important genera throughout the world, have the potential to meet out the requirement of wood with fast growth rate at short durations. The genus *Populus* belongs to family Salicaceae of which 40 species found naturally growing in the temperate and sub-tropical regions of northern hemisphere. It is a major supplier of industrial wood and fibre in many countries. *Populus deltoides* Bartr. Ex Marsh (local name Poplar), native of North America, was introduced in India in 1950. It is a fast growing tree producing soft wood of multifarious uses viz. plywood, pulp, matchwood, veneer, light furniture and packing cases. Besides, wood can be used for sports goods, fibreboard, pencil making, etc. its straight stem. Thin crown, deciduous nature and short rotation are some of the good characteristics to make it suitable into agro-forestry models. Further, the economic returns from poplar are also quite remunerative. According to an estimate, the total biomass of 8-year-old *P. deltoides* plantation in tarai region of central Himalaya was calculated 202.59 t/ha and single tree accounts about 0.405 t biomass. The above ground components contribute 78.68% and below ground components contributed 21.32% to the total biomass (Singh and Lodhiyal, 2009). *Populous deltoides* grows better on well-drained fertile soils having neutral soil pH. Farmers have started raising poplar on large scale as block / boundary plantations in the states of Punjab, Haryana, Uttar Pradesh, Uttaranchal and Himachal Pradesh.

Agroforestry system has a great scope in sequestering the above-ground and below-ground soil carbon and helps in mitigating the greenhouse effect by reducing carbon emissions (Albrecht and Kandji, 2003) [2]. Carbon can be sequestered in the mineral soil after the conversion of intensively cropped agricultural fields to more extensive land uses such as afforested ecosystems. Understanding the agroforestry systems that involve greater diversity and complexity has become a research interest worldwide posing fundamental questions like carbon sequestration (Puri and Nair, 2004). It has been estimated that the poplar based agroforestry system has great potential for restoration of degraded lands and forests and mitigating the accumulation of carbon as CO_2 in the atmosphere by increasing land-based carbon sinks. The Intergovernmental Panel on Climate Change (IPCC) recognized poplar based agroforestry system as having high potential for sequestering carbon under climate change mitigation strategies (Watson *et al.*, 2000) [4]. The importance of poplar based agroforestry system as a viable alternative to prevent and mitigate climate change has also

been recognized widely in India. At the national level, planting of poplar may lead to carbon sequestration of more than 542 kt yr^{-1} when wood products are not accounted for and about 1 Mt yr^{-1} inclusive of wood products (Gera, 2012) [5]. In Yamunanagar and Saharanpur districts of Haryana and Uttar Pradesh states of India, carbon storage was estimated to be 27–32 Mg ha^{-1} in boundary systems and 66–83 Mg ha^{-1} in agroforestry systems at a rotation period of 7 years (Rizvi *et al.*, 2011) [6] while Kanime *et al.* (2013) [7] reported values of 4.51 Mg ha^{-1} in boundary plantation and 28.7 Mg ha^{-1} in block plantation at Pantnagar, India. In Punjab, India, Chauhan *et al.* (2010) [8] reported that total biomass carbon storage after 7 years was equivalent to 62.48 Mg ha^{-1} (8.92 Mg ha^{-1} yr^{-1}). Arora *et al.* (2014) [9] reported that average long-lived carbon sequestration rate and long + short-lived sequestration rate were 2.11 and 6.07 Mg ha^{-1} yr^{-1} respectively. Dhiman (2009) [10] estimated that only 1.04 Mt out of 2.5 Mt carbon from poplar production systems in India is sequestered in wood-based products; the remainder is released to the atmosphere in the form of fuel and only a marginal fraction of 0.3 Mt carbon is added to soil through leaf litter every year. Hence, keeping in view the importance of poplar based agroforestry system the study was conducted to determine the carbon sequestration potential of poplar based agroforestry system and its effect on the soil physio-chemical properties.

Materials and Methods

The present study was conducted in the already established 8 years old poplar plantation spaced at the spacing of 5 m x 4 m, 10 x 2 m and 18 x 2 x 2m at CCS Haryana Agricultural University, Hisar (29º09' N latitude and 75º43' E longitude at an elevation of 215 m above mean sea level), situated in the semi-arid region of North-Western India. The climate is subtropical-monsoonic with an average annual rainfall of 350-400 mm, 70-80 per cent of which occurs during July to September. The summer months are very hot with maximum temperature ranging from 40 to 45 ºC in May and June whereas, December and January are the coldest months (lowest January temperature as low as 0 ºC). The textural class of the soil is 'sandy loam' and the soil of the experiment site is medium in organic carbon, available N, P and K (Table 1).

The trees at random on in all the spacings were measured for their top height and girth at breast height (GBH). The total height was measured from ground to top of the trees. The total height was measured from ground to top of the trees. The girth at breast height (1.37 m above the ground level) was taken. Standing volume of timber tree was calculated as: Total volume (m^3) = π $(D/2)^2$ X h, Where, π = 3.14; D = DBH (m) and h= Height of tree (m). The above ground biomass was calculated: Biomass = volume X specific gravity of wood. The below ground biomass of poplar was calculated using IPCC (2003) [11] default value (0.26). To estimate the biological yield of agricultural crops, plants were uprooted to the depth possible in $1m^2$ plot (mean of three plots/system/intercrop) under different spacings of poplar based agroforestry system. Fresh weight (above and below ground) was taken and hereafter, the representative samples, from all treatment and replications were taken and brought to laboratory and dried in oven at 60 ^{0}C till the constant weight to record dry weight. Biological yield was calculated using formula:

$$\text{Biomass of leaves} = \frac{\text{Dry weight of sample}}{\text{Fresh weight of sample}} \text{ x Total fresh weight of branch/leaves}$$

The carbon sequestration in respective agroforestry systems was calculated by using default value 0.48 for Indian conditions (Chaturvedi, 1984) [12].

Results and Discussion

Growth of poplar

The mean height and GBH of poplar increased from 6.59 and 16.92 cm (1 year old plantation) to 19.55 m and 77.94 cm (8 year plantation), respectively. The height of poplar after 8 years of plantation was not affected significantly at different spacings under agroforestry based system (Table 2). However, different sapcing's had significant effect on the girth of poplar. Paired row planting (18x2x2 m) of poplar resulted in significantly lesser girth (70.9 cm) than planting of poplar at 10x2 m (81.53 cm) and 5x4 m (81.38 cm) spacings due to increased competition among plants for different growth resources. However, statistically non-significantly variation for girth was observed between 10x2 m and 5x4 m spacings. Mean annual increment (MAI) also exhibited non-significant variations for height but significant differences for girth under different spacings of poplar. Interestingly, more than 9.0 cm MAI for girth was estimated at 10x2 m and 5x4 m spacings indicating that these spacings are convivial for optimal increase in girth of poplar plantations under agroforestry system. Similar trends in growth of poplar under different spacings in irrigated eco-system with slight variable values have been reported by several research workers (Nissen *et al.*, 2001; Dogra *et al.*, 2007; Chauhan *et al.*, 2012 and Dhillon *et al.*, 2016) [13, 14, 15, 16].

Carbon sequestration

The poplar based agroforestry system improves aggregation of soil through huge quantity of organic matter in the form of leaf biomass. The extent of improvement may be affected by the age of the poplar trees. The soil under poplar based agroforestry system showed 39.7 per cent more organic carbon than sole crop. The soils under poplar based agroforestry had 2.9–4.4 Mg ha^{-1} higher soil organic carbon than in sole crop (Table 3). Present study revealed that poplar based agroforestry had tremendously higher carbon storage potential than sole agriculture. The sequestration was 119, 101 and 84 per cent higher at 5x4 m, 10x2 m and 18x2x2 m spacing of poplar than sorghum-berseem crop rotation in sole agriculture, respectively. Due to less crop biomass production in cowpea- wheat crop rotation in sole crops, carbon storage under agroforestry was 139, 121 and 98 per cent higher at 5x4 m, 10x2 m and 18x2x2 m spacing than the sole crops, respectively. The mean rate of carbon storage in agroforestry has been found to be 113 per cent higher than sole Agriculture. The rate of carbon storage was found to be 25.2 t/ha/year in poplar based agroforestry system and 11.8 t/ha/year in sole agriculture. Sathaye and Ravindernath (1998) [17] have also reported average sequestration potential in agroforestry system to be 25 tC ha^{-1}. Yadava (2010) [18] estimated carbon sequestered under agroforestry system involving eucalyptus + wheat in Himalayan Tarai region to be 14.42 t ha^{-1} and about 32 t ha^{-1} under various agroforestry systems involving poplar as woody component. Similarly, Bohre *et al.*, (2013) [19] estimated per tree carbon stocks to the

tune of 76.6 kg tree^{-1} at the age of 20 years in teak plantations. Moreover, the carbon stored in tree component is locked for a long time whereas the carbon in crops is locked for a short period only.

The study evinced that carbon stocks contribution of woody perennials is higher in systems involving closer spacings (5x4 m). In the initial year, the woody component has lesser biomass per hectare however with the advancement of age of poplar carbon stocks increase considerably thereby increasing the total shares in overall carbon stock of poplar based agroforestry system. Hence, it can be concluded that the amount of carbon sequestered largely depends on the geometry of perennial component in an agroforestry system. Other factors influencing carbon storage in agroforestry systems include tree species and system management (Albrecht and Kandji, 2003) [2].

Table 1: Soil chemical properties of the experiment field before sowing of the agricultural crop

Spacing (m)	pH (1:2)	EC dS m^{-1}	OC (%)	Available Nutrients (Kg ha^{-1})		
				N	P	K
5 x 4	7.8	0.12	0.72	340	18.3	364
10 x 2	7.8	0.10	0.66	317	16.1	345
18 x 2 x 2	7.9	0.14	0.62	278	13.4	332
Sole crop	7.9	0.22	0.39	228	9.5	385

Table 2: Growth performance of poplar under agroforestry system

Spacing (m)	Tree height (m)			GBH (cm)		
	1 year age	8 year age	MAI	1 year age	8 year age	MAI
5 x 4	6.55	19.60	1.86	17.65	81.38	9.10
10 x 2	6.62	20.15	1.93	17.59	81.53	9.13
18 x 2 x 2	6.60	18.90	1.76	15.51	70.90	7.91
Mean	6.59	19.55	1.85	16.92	77.94	8.71
CD (p=0.05)	NS	NS	NS	0.5	2.6	0.9

Table 3: Total carbon storage (t/ha) in poplar based Agroforestry system and sole agriculture after eight years of plantation

System	Carbon storage (t/ha)			
	Poplar spacings (m)			Sole Crops
	5x4	10x2	18x2x2	
Soil	**13.9**	**13.5**	**12.4**	**9.5**
Agril. crops (above ground)				
A. Sorghum-berseem	18.5	22.7	26.2	41.4
B. Cowpea-wheat	15.9	19.3	21.1	35.2
Poplar tree (below & above ground)	77.4	63.3	55.2	-
Grand total =				
poplar+sorghum-berseem	114.7	102.5	93.8	50.9
poplar + cowpea-wheat	107.2	99.1	88.7	44.7
Carbon storage rate / year/ ha				
Sole poplar	9.7	8.3	6.9	-
Poplar+sorghum-berseem	14.3	12.8	11.7	6.3
Poplar+cowpea-wheat	13.4	12.4	11.1	5.5

References

1. Singh P, Lodhiyal LS. Biomass and carbon allocation in 8-year-old poplar (*Populus deltoides* Marsh) plantation in Tarai agroforestry systems of central Himalaya, India. New York Science Journal. 2009; 2:49-53.
2. Albrecht A, Kandji ST. Carbon sequestration in tropical agroforestry system. Agriculture, Ecosystem and Environemnt. 2003; 99:15-27.
3. Puri S, Nair PKR. Agroforestry research for development in India: 25 years of experiences of a national program. Agroforestry system. 2004; 61:437-452.
4. Watson RT, Noble IR, Bolin B, Ravindranath NH, Verardo DJ, Dokken DJ. Land use, land-use change, and forestry: A special report of the IPCC. Cambridge, Cambridge University Press, 2000.
5. Gera M. Poplar culture for speedy carbon sequestration in India: a case study from Terai region of Uttarakhand. Envis Forestry Bulletin. 2012; 12:75-83.
6. Rizvi RH, Dhyani SK, Yadav RS, Singh R. Biomass production and carbon stock of poplar agroforestry systems in Yamunagar and Saharanpur districts of northwest India. Current Science. 2011; 100:736-742.
7. Kanime N, Kaushal R, Tewari SK, Chaturvedi OP. Biomass production and carbon sequestration in different tree-based systems of Central Himalayan Tarai region. Forest Trees and Livelihoods. 2013; 22(1):38-50
8. Chauhan SK, Sharma SC, Beri V, Ritu Yadav S, Gupta N. Accounting poplar and wheat productivity for carbon sequestration agri-silvicultural system. Indian Forester. 2010; 136:1174-1182.
9. Arora G, Chaturvedi S, Kaushal R, Nain A, Tewari S, Alam NM *et al*. Growth, biomass, carbon stocks, and sequestration in an age series *of Populus deltoides* plantations in Tarai region of central Himalaya. Turkish Journal of Agriculture and Forestry. 2014; 38:550-560.
10. Dhiman RC. Carbon footprint of planted poplar in India 2009. ENVIS Forestry Bulletin. 2009; 9:70-81.
11. IPCC. Good practice guidance for LULUCF Sector. Intergovernmental panel on climate change. Cambridge University Press, Cambridge, UK, 2003.
12. Chaturvedi AN. Sequestration of atmospheric carbon in Indian forest. Ambiology. 1984; 23:460-461.
13. Nissen TM, Midmore DJ, Keeler AG. Biophysical and economic tradeoffs of intercropping timber with food crops in the Philippine uplands. Agricultural Systems. 2001; 67:49-69.
14. Dogra AS, Upadhyay A, Sharma SC, Chauhan SK. Potential of agroforestry as a land use option in Punjab, India. Indian Forester. 2007; 133:1437-1448.
15. Chauhan SK, Brar MS, Sharma R. Performance of poplar (*Populus deltoids* Bart.) and its effet on wheat yield under agroforestry system in irrigated agro-ecosystem,

India. Caspian Journal of Environmental Sciences. 2012; 10:53-60.
16. Dhillon RS, Bhardwaj KK, Beniwal RS, Bangarwa KS, Kumari S, Godara AS *et al*. Performance of wheat as intercrop under different spacings of poplar plantations in semi-arid ecosystem of Northern India. Indian Journal of Ecology. 2016; 43(1):323-327.
17. Sathaye JA, Ravindernath NH. Climate change mitigation in the energy and forestry sectors of developing countries. Annual Review of Energy and the Environment. 1998; 23:387-437.
18. Yadava AK. Carbon Sequestration: underexploited environmental benefits of Tarai agroforestry systems. Report and Opinion. 2010; 2(11):234-244.
19. Bohre P, Chaubey OP, Singha PK. Biomass accumulation and carbon sequestration in *Tectona grandis* Linn. f. and *Gmelina arborea* Roxb. International Journal of Bio-Science and Bio-Technology. 2013; 5(3):153-174.