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Growth, Biomass and Carbon Sequestration of *Populus deltoides* Clones

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ABSTRACT

To study the growth performance of twenty clone viz. G - 48, AM - 48, AM - 49, AM - 41, BR - 510, AM - 50, FS - 18, FS - 190, FS - 155, L - 90, L - 87, L - 89, S7 C 1, S7 C15, S7 C20, S7 C4, L - 200 - 84, Bahar, Udai and Kranti of *Populus deltoides* at Prayagraj, Uttar Pradesh. The experiment was established in year February 2018 and growth performance data were recorded after 4 years in February 2022. The maximum height was found in Udai (11.57 ± 0.23 m) followed by L - 87 (10.22 ± 0.42 m) and minimum in Bahar (6.74 ± 0.19 m) whereas the maximum diameter was found in L - 87 (10.79 ± 0.63 cm) followed by S7 C1, (10.63 ± 0.33 cm) and minimum in Bahar (4.97 ± 0.06 cm). The maximum basal area L 87 (91.39 cm^2 $tree^{-1}$) followed by S7 C1 (88.70 cm^2 $tree^{-1}$) and minimum in Bahar (19.39 cm^2 $tree^{-1}$) whereas maximum volume Udai (1386.66 m^3ha^{-1}) followed by L-87 (1303.37 m^3ha^{-1}) and minimum in Bahar (182.37 m^3ha^{-1}). The biomass, carbon stock and carbon sequestration in poplar was maximum in Udai followed by L- 87 and minimum in Bahar for biomass (1146.59, 1077.22 and 150.79 t ha^{-1}) carbon stock (573.30, 538.86 and 75.40 t ha^{-1}) and carbon sequestration (2104.00, 1977.62 and 276.71 t ha^{-1}) respectively.

Keywords Poplar clones, Growth, Biomass, Carbon stock, Carbon sequestration.

INTRODUCTION

Populus deltoides, a cottonwood poplar native to North America is popular choice among farmers because of its fast growth rate, ease of harvest, superior tree–crop interactions, high yield, remunerative returns and ease of marketing. The first systematic and scientific effort to introduce poplar clones in Uttar Pradesh (now Uttarakhand) was done by Forest Department in 1950. From 1976 onwards, WIMCO and NABARD pioneered the expansion of this tree for wide-scale plantation in Punjab, Haryana and western Uttar Pradesh (Chavan and Dhillion 2019, Chaturvedi 2017, ICFRE 2012).

Poplar is widely used for commercial purpose in North India for a variety of purposes, ranging from plywood to pencil manufacturing. It is widely accepted tree in agroforestry method and planted in boundary planting, block plantation and intercropping, with wheat and sugarcane being the most common crops

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(Chavan and Dhillion 2019).

Poplar is well suited to production of veneer for match industry, fiber board, light packing cases, paper and pulp. This species can be grown in forest area as pure plantation and intercrops (Chaturvedi 1981, Jha and Gupta 1991) as well as outside forests along roads, canals and farm lands (Dalal and Trigotra 1983, Singh *et al.* 1988). According to Tariq and Khanna (2012) packaging industry uses 80% of poplar trees while veneer, plywood, cricket bat handles, scaffolding, and roofing uses remaining 20% of total wood production of poplar.

MATERIALS AND METHODS

Poplar experiment was established in year February 2018 at Prayagraj, Uttar Pradesh. The longitude (25.54°N) and latitude (81.89°E) of plantation site. In this experiment 20 clones of poplar which was collected from ICFRE, Dehradun and cutting were planted in 1.5 × 1.5 m spacing. Poplar clones viz. G - 48, AM - 48, AM - 49, AM - 41, BR - 510, AM - 50, FS - 18, FS - 190, FS - 155, L - 90, L - 87, L - 89, S -7 C - 1, S - 7 C 15, S - 7 C - 20, S - 7 C - 4, L - 200 - 84, Bahar, Udai and Kranti. The growth performance data were recorded after 4th year February 2022.

Diameter was recorded at breast height of standing tree with calliper at 1.37 m above ground level. The height of standing trees was documented using a clinometer. Number of branches were counted individual tree. Calculation of basal area using following formula.

$$BA = \pi \left(\frac{d}{2}\right)^2$$

Where, BA is Basal area (cm^2) and d (cm) is the diameter

For the calculation of volume diameter was converted in girth at breast level. Volume of the trees was calculated using the quarter girth method as follows.

$$V = \left(\frac{g}{4}\right)^2 \times h$$

Where V is the volume (m^3), g the (GHB) girth at breast height (m) and h is the height of the tree (m).

Above Ground Biomass (AGB) : For estimation of AGB, volume was multiplied by wood density (WD) of the tree and biomass expansion factor (BEF). The stem wood biomass was then 'expanded' to entire AGB of the tree, including leaves, twigs, branches, bole and bark using BEF (Bohre *et al.* 2013, Singh *et al.* 2022). For this study BFF value of 1.5 was used (Brown and Lung 1992, Chauhan *et al.* 2019b).

$$AGB\ (t\ ha^{-1}) = Volume\ (m^3) \times WD \times BEF$$

Below Ground Biomass (BGB) : For estimation of below ground biomass, above ground biomass was multiplied with the factor 0.25 (IPCC 2006).

$$BGB\ (t\ ha^{-1}) = AGB \times 0.25$$

Total Biomass (TB) : The total biomass was calculated by addition of biomass of all the components (Below ground and above ground).

$$TB\ (t\ ha^{-1}) = AGB + BGB$$

The carbon storage for each tree was estimated by multiplying biomass values with carbon concentration usually taken as 0.50 (default value given by (IPCC 1996) and was expressed in t tree^{-1} and t ha^{-1}and total carbon stock (t ha^{-1}) were adopted by the same process (Singh *et al.* 2022, Tudu *et al.* 2021, Toppo *et al.* 2021). Carbon sequestration in tree per hectare was dependent on tree density. It was expressed in t ha^{-1}.

$$Carbon\ stock\ (t\ ha^{-1}) = TB\ (t\ ha^{-1}) \times CF$$

Here carbon stock was multiplied by 44/12 to assessment CO_2 sequestration (Singh *et al.* 2022, Tudu *et al.* 2021).

Data were analyzed by using descriptive statistics and presented as mean and standard error of mean. Statistical analysis was conducted using 'Excel Package of MS Office 2019.

RESULTS AND DISCUSSION

Performance of height, diameter and number of

Table 1. Height, diameter and number of branches of *Populus deltoides*.

Clone	Height (m)	Diameter (cm)	Number of branches
G - 48	7.72 ± 0.22	6.18 ± 0.36	17.60 ± 4.74
AM - 48	7.82 ± 0.18	7.15 ± 0.68	11.60 ± 1.94
AM - 49	7.56 ± 0.24	7.14 ± 0.20	12.00 ± 0.32
AM - 41	7.73 ± 0.19	5.35 ±0.33	15.00 ± 3.52
BR - 510	7.40 ± 0.40	5.62 ± 0.24	16.20 ± 3.83
AM - 50	8.30 ± 0.11	5.44 ± 0.22	10.00 ± 2.59
FS - 18	8.21 ± 0.18	5.5 ± 0.19	7.80 ± 0.86
FS - 190	8.22 ± 0.20	5.85 ± 0.16	11.40 ± 3.25
FS - 155	8.11 ± 0.23	7.01 ± 0.38	14.00 ± 1.87
L - 90	8.10 ± 0.10	6.99 ± 0.19	9.25 ± 0.48
L - 87	10.22 ± 0.42	10.79 ± 0.63	21.00 ± 4.88
L - 89	7.67 ± 0.25	7.02 ± 0.13	7.50 ± 4.50
S7 C1	9.93 ± 0.69	10.63 ± 0.33	14.75 ± 4.82
S7 C15	8.25 ± 0.25	8.13 ± 0.41	10.80 ± 1.46
S7 C20	9.42 ± 0.91	8.17 ± 0.34	12.60 ± 4.40
S7 C4	9.37 ± 0.37	8.16 ± 0.41	13.75 ± 3.84
L - 200 -84	10.14 ± 0.51	9.79 ± 0.49	15.8 ± 3.75
Bahar	6.74 ± 0.19	4.97 ± 0.06	6.00 ± 2.31
Udai	11.57 ± 0.23	10.46 ± 0.55	19.40 ± 4.19
Kranti	9.34 ± 0.51	9.01 ± 0.72	11.40 ± 3.79

branches was shown in Table 1. The data indicated that the maximum height was found in Udai (11.57 ± 0.23 m) followed by L - 87 (10.22 ± 0.42 m) and minimum in Bahar (6.74 ± 0.19 m) whereas the maximum diameter was found in L - 87 (10.79 ± 0.63 cm) followed by S7 C1 (10.63 ± 0.33 cm) and minimum in Bahar (4.97 ± 0.06 cm). Maximum number of branches found in L-87 (21.00 ± 4.88) followed by Udai (19.40 ± 4.19) and minimum in Bahar (6.00 ± 2.31). According to Karnatka and Chandra (1995) the growth performance of five clones, namely Udai, Kranti, Bahar, 72/58 and ST-74 was comparable to that of clone G-48, with Udai and Kranti outperforming Bahar. Similar result found by Luna *et al.* (2012) where 12 poplar clones of 3 years of age were evaluated at Kharkan Research Station, Hoshiarpur (Punjab). The clone WSL - 39 found maximum attaining diameter of 14.74 cm and height 14.42 m. Chauhan *et al.* (2015) reported the six years old poplar boundary plantation DBH (24.23 cm) than the block plantation (19.71 cm). Tomar and Srivastav (2020) reflected maximum height and diameter in poplar clone L-200-84 followed by Udai at Prayagraj, Uttar Pradesh. Dhillon *et al.* (2020) found the poplar plant height varied from 4.31 to 5.38 m during 2 years. Clone L-7/87 recorded the top rank for height with value of 5.38 m and was higher to all poplar clones except L-34/82. Clone L-34/82 was however at par with seven other clones i.e., 22-N, L-48/89, S7C8, WSL-22, L-247/84, L-50/88 and Ranikhet.

Basal area and volume, was shown in Table 2.

Table 2. Volume, biomass, carbon stock and carbon sequestration of poplar plantation.

Clone	Basal aera cm^2 $tree^{-1}$	Volume m^3ha^{-1}	ABG t ha^{-1}	BGB t ha^{-1}	TB t ha^{-1}	Carbon stock t ha^{-1}	Carbon sequestration t ha^{-1}
G - 48	29.98	322.97	213.65	53.41	267.06	133.53	490.05
AM - 48	40.13	437.92	289.68	72.42	362.10	181.05	664.46
AM - 49	40.02	422.17	279.27	69.82	349.09	174.54	640.57
AM - 41	22.47	242.36	160.32	40.08	200.40	100.20	367.74
BR - 510	24.79	256.02	169.36	42.34	211.70	105.85	388.47
AM - 50	23.23	269.00	177.94	44.49	222.43	111.21	408.15
FS - 18	23.75	272.18	180.05	45.01	225.06	112.53	412.98
FS - 190	26.86	308.30	203.94	50.98	254.92	127.46	467.78
FS - 155	38.62	437.26	289.25	72.31	361.56	180.78	663.46
L - 90	38.40	434.23	287.25	71.81	359.06	179.53	658.87
L - 87	91.39	1303.37	862.18	215.54	1077.72	538.86	1977.62
L - 89	38.66	413.59	273.59	68.40	341.99	170.99	627.54
S7 C1	88.70	1229.35	813.22	203.30	1016.52	508.26	1865.32
S7 C15	51.89	597.03	394.94	98.73	493.67	246.84	905.89
S7 C20	52.40	688.76	455.62	113.90	569.52	284.76	1045.07
S7 C4	52.27	683.57	452.18	113.05	565.23	282.62	1037.20
L - 200 -84	75.24	1064.58	704.22	176.05	880.27	440.14	1615.30
Bahar	19.39	182.37	120.64	30.16	150.79	75.40	276.71
Udai	85.89	1386.66	917.28	229.32	1146.59	573.30	2104.00
Kranti	63.73	830.56	549.41	137.35	686.77	343.38	1260.22

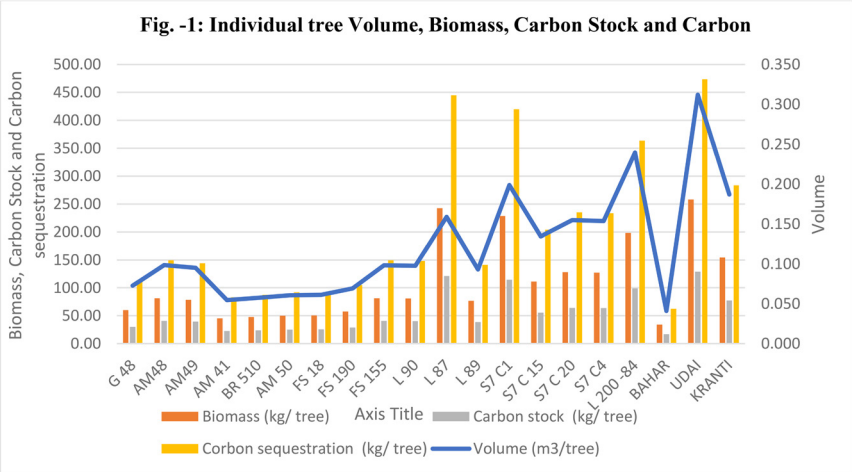

Fig. 1. Individual tree volume, biomass, carbon stock and carbon sequestration of different clones.

The data indicated the maximum basal area L 87 (91.39 cm^2 $tree^{-1}$) followed by S7 C1 (88.70 cm^2 $tree^{-1}$) and minimum in Bahar (19.39 cm^2 $tree^{-1}$) whereas maximum volume Udai (1386.66 m^3ha^{-1}) followed by L-87 (1303.37 m^3 ha^{-1}), and minimum in Bahar (182.37 m^3ha^{-1}). Individual volume, biomass, carbon stock and carbon sequestration of single tree presented in Fig. 1. Similar result was reported by Luna *et al.* (2012) at Punjab where among 12 clones of poplar the clone WSL – 39 shown maximum volume 0.013, 0.0556, 0.104 m^3 at the age of 1, 2 and 3 years, respectively.

The biomass, carbon stock and carbon sequestration of poplar tree was found maximum in Udai followed by L-87 and minimum in Bahar, for biomass (1146.59, 1077.22 and 150.79 t ha^{-1}) carbon stock (573.30, 538.86 and 75.40 t ha^{-1}) and carbon sequestration (2104.00, 1977.62 and 276.71 t ha^{-1}) respectively shown in Table 2. Chavan *et al.* (2022) found the total dry biomass production of poplar varied from 69.90 to 207.98 Mg ha^{-1} in aboveground and 13.46 to 36.69 Mg ha^{-1} in belowground after eight-years at Hisar, Haryana. Sarangle *et al.* (2018) in poplar based land use systems found biomass 181.01 t ha^{-1}, carbon stock 97.29 t ha^{-1} and carbon sequestration 18.59 t C ha^{-1} yr^{-1} at Punjab. Kumar *et al.* (2020) found the poplar biomass 25.702 t ha^{-1}, carbon stock 11.460 t ha^{-1}, carbon sequestration 42.049 t ha^{-1} at Pantnagar, Swamy and Mishra (2014) reported the total carbon storage in *P. deltoides* from 22.5 to 30.1 Mg ha^{-1} at Chhattisgarh. Chauhan *et al.* (2015) studied six years old poplar trees and recorded that total carbon storage was higher in block planting method (55.43 t ha^{-1}) than in boundary plantation (32.70 tha^{-1}) and lowest total carbon storage in sole cropping system (31.20 tha^{-1}). The total carbon storage under spacings viz. 5 × 4 m, 10 × 2 m, 18 × 2 × 2 m, poplar was 112.48, 101.80, 84.87, 77.28 and 38.84 Mg C ha^{-1}, respectively. The carbon sequestration was maximum in 5 × 4 m (14.09 Mg C ha^{-1} yr^{-1}) followed by 10 × 2 m (12.61 Mg C ha^{-1} yr^{-1}), 18 × 2 × 2 m (10.50 Mg C ha^{-1} yr^{-1}), East–West (9.56 Mg C ha^{-1} yr^{-1}) and North–South plantation (4.80 Mg C ha^{-1} yr^{-1}) after eight-years at Hisar, Haryana reported Chavan *et al.* (2022).

Table 3. Multiple correlation between different clones of poplar height, diameter, branch, basal area, volume and biomass parameters.

	Height	Diameter	Branch	Basal area	Volume	Biomass
Height	1.000					
Diameter	0.876	1.000				
Branch	0.601	0.564	1.000			
Basal area	0.887	0.995	0.587	1.000		
Volume	0.931	0.976	0.619	0.990	1.000	
Biomass	0.931	0.976	0.619	0.990	1.000	1.000

Multiple correlation between different clones of poplar on independent variable height, diameter,

branch, basal area, volume and biomass

The correlation matrix between the height, diameter, number of branches, basal area, volume and biomass is shown in Table 3. Diameter was significantly correlated with height (0.876), while branch was significantly correlated with height (0.601) and diameter (0.564). Basal area was significantly correlated with height (0.887), diameter (0.995), branch (0.587). Volume was significantly correlated with height (0.931), diameter (0.976), branch (0.619) and basal area (0.990). Biomass was significantly correlated with height (0.931), diameter (0.976), branch (0.619), basal area (0.990) and volume (1.000).

CONCLUSION

The results reveal that three poplar clones viz. Udai, L-87 and S7 C1 were better adapted to early growth in the Prayagraj region. However, these were preliminary growth results, with modest juvenile mature correlations to be expected and growth monitoring will be continued in this trial series to confirm the identification of suitable clones for the region. The discovery of promising clones for the region will pave the way for farmers to use this species more broadly in agroforestry. Supply of adequate poplar planting material will be a benefit for local farmers looking to boost their income through agroforestry. The evaluation of poplar clones' performance in future years will support in the identification of promising clones for a given region, allowing planting stock of desired clones to be raised for field cultivation. The increase of poplar plantations in agroforestry will relief in reducing forest pressure and growing trees outside of forests.

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