G- Journal of Environmental Science and Technology

(An International Peer Reviewed Research Journal)

Available online at http://www.gjestenv.com

Growth, Biomass and Carbon Sequestration Potential of Different Poplar (*Populus deltoides* Bartr.) clones in Agroforestry System with Wheat (*Triticum aestivum)* Varieties in *tarai* belt of Uttarakhand

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ARTICLE INFO

Received: **13 Oct 2017**
Revised: **12 Nov 2017**
Accepted: **28 Dec 2017**

***Key words*:** Poplar clone, diameter at breast height, height, leaf, stem, branch, root biomass, carbon sequestration

ABSTRACT

For two years, field experiments were carried out at Agro-Forestry Research Center of G.B.P.U.A. & T., Pantnagar, Uttarakhand (29°N Latitude, 79° 30' E longitude and at an altitude of 243.84 msl) during 2013-14 and 2014-15, to study the growth, biomass and carbon sequestration potentials of poplar clones in association with different wheat varieties in a sandy loam soil. The soil of the experimental site contained 1.175% of organic carbon, 259, 20 and 195 kg/ha available nitrogen, phosphorus and potassium, respectively. The soil was almost neutral in reaction (pH 8.2). The study was laid in split plot with poplar tree clones viz., S7C8, G-48, W-39 and Kranti in main plots and wheat varieties viz., DBW-17, PBW-502, UP-2748 and HD-2967 in sub-plots. Poplar trees were planted at spacing of 7.0 m x 3.0 m.

Poplar clones S7C8 in 2013-14 and Kranti in 2014-15 recorded higher values of diameter at breast height (DBH) and tree height than clones W-39 and G-48. Wheat variety DBW-17 exhibited higher values of poplar growth than varieties PBW-502 and UP-2748. In 2013-14 clone S7C8 recorded the highest values of different components of trees biomass. In 2014-15, clone Kranti produced significantly higher stem, roots and total biomass than clones G-48 and W-39. The total carbon sequestered by the agroforestry system during both the years, was the highest with the clone Kranti (57.14 t/ha in 2013-14 and 65.69 t/ha in 2014-15). In 2014-15, the total carbon sequestered by clone Kranti was significantly higher than other clones. The total carbon sequestered by the agroforestry system was the lowest with the clone G-48.

Except carbon stock in wheat plant biomass, wheat varieties did not affect the poplar growth, biomass and carbon stock of the agroforestry system significantly. Wheat variety DBW-17 in 2013-14 and HD-2967 in 2014-15 recorded the highest amount of carbon in plant biomass.

1) INTRODUCTION

Agroforestry is an ideal land use option as it optimizes trade-offs between increasing food production, poverty alleviation and environmental conservation [1]. Agricultural lands are believed to be a major potential sink and can absorb large quantities of carbon, if trees are introduced and judiciously managed with crops [2, 3]**.** Thus, agroforestry system is a better climate change mitigation option than crops alone. Agroforestry practices also have wide and promising potential to store carbon and remove atmospheric carbon dioxide through enhanced growth of trees and shrubs for a longer period. The carbon storage in the agroforestry system in above and below ground biomass and soil has been expected to be greater than that in a conventional agricultural operation [4,5]**.** Watson et al., [3] estimated carbon gain of 0.72 Mg C/ha/yr on 4000 million ha and under agroforestry, with potential for sequestering 26 Tg C/yr by 2010 and 45 Tg C/yr by 2040. Although agroforestry is not a new concept, but its form has changed in the present context. Contrary to old natural systems, the present systems are created with a specific objective so as to maximize the benefits besides sustaining the land and environment.

In the modern agriculture, Poplar has become the first choice of the growers in the agroforestry system as it is a deciduous tree and field crops can successfully be integrated with it. Continuous efforts are under way to improve the potential of poplar. Spanos [6] found that widely used clone I-214 produced the lowest biomass yield, whereas a significant number of other clones achieved acceptable biomass quantities. The plant tree biomass and architecture affect the performance of under story crops as well as the soil properties. Wheat is popular crop being grown in inter tree spaces of the poplar trees. Chauhan [7] found that the carbon storage in agroforestry system was substantially higher as compared to sole crop. The carbon storage in agroforestry system increased with the age of the plantation and the major contribution came from the timber, roots and litters. Puri et al., [8] observed that clones of 4 years had an increment of diameter at breast height (DBH) by 66.5 to 77.5% and of height by 42.2 to 78.6% within one year when compared to that observed at 3 years of age. In rank order of growth, the best five clones were 65/27 >

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G3 > D121 > G48 > S7C1. Mishra et al., [9] studied variations in growth and above and below ground biomass of five promising clones (G3, G48, 65/27, D121 and S7C1) of *Populus deltoides.* Diameter at breast height (DBH) and tree height were consistently higher in clone 65/27 and lowest in clone S7C1. Tree total biomass varied from 48.5 to 62.2 Mg/ha in 6-year-old clones and it followed the order 65/27 > D121 > G48 > G3 > S7C1. Stem wood accounted for 60.4 - 68.9% of total biomass, followed by coarse roots (12.2 - 18.9%), branches (12.3 -15.0%), leaves (3.02 - 6.90%) and fine roots (1.5 - 2.7%).

Hence, great variability persists among poplar with respect to growth and biomass accumulation and carbon sequestration capacity. It is therefore pertinent to evaluate different newly developed poplar clones and wheat varieties to have a potential agroforestry system option. The present study therefore was undertaken to study the potentials of different poplar clones with wheat varieties in *tarai* region of the Uttarakhand state.

2) MATERIALS AND METHODS

For two years field experiments were conducted at Agroforestry Research Centre, G. B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand (29°N Latitude, 79° 30' E longitude and at an altitude of 243.84 m amsl) during *rabi* seasons of 2013-14 and 2014-15. The field comprised sandy loam soil with 1.175% of organic carbon, 259, 20 and 195 kg/ha available nitrogen, phosphorus and potassium, respectively. The mean annual rainfall of the region is 1400 mm, out of which 80 to 90% is received during rainy season (between June and September) and remaining 10 to 20% during winter season (November to April). The climate of the region is characterized by a humid sub-tropical, cold and hot dry summers.

The experiment was laid in a split plot design with poplar tree species in main plot and wheat varieties in sub-plots, replicated thrice. Four different clones of poplar viz., S_7C_8, G-48, W-39 and Kranti were planted in 2012 at spacing of 7.0 m x 3.0 m (total 476 trees/ha). The four wheat varieties viz., DBW- 17, PBW-502, UP-2748 and HD-2967 were sown at row-to-row distance of 20 cm on both sides of the tree line using 100 kg seed/ha. The wheat was supplied with 120:60:40 kg N- P_2O_5- K_2O/ha. The half dose of N and full dose of P and K were applied as basal. The remaining nitrogen in equal splits was applied after crown root initiation stage and pre-heading stage, respectively. Three irrigations were applied to the crop coinciding with crown root initiation (21 days after sowing), late jointing (65 DAS) and milking stage (105 DAS) during both the years.

Form each replication three trees were randomly selected for growth observations. The stem diameter was measured with the help of diameter caliper at 1.37 m height above the ground level. The average stem diameter was depicted as diameter at breast height (cm). The tree height was measured with the help of a wooden rod (bamboo) and expressed in meter/tree. The stem biomass was calculated by the equation developed by Arora et al., [10] for *Tarai* region. The developed equation was: $Y = a \times D^b$

Where,
Y: The stem biomass kg/tree
D: Diameter at breast height (cm)
a& b are the coefficients (a= 0.038 and b= 2.85)

Total number of branches irrespective of size were counted on each of the sample tree and then categorized on the basis of basal diameter into small, medium and large groups. Fresh weight of two sampled branches from each group was recorded separately. The formula given by Chidumaya [11] was used to determine the dry weight of branches. Leaves from the harvested branches were removed, weighed and oven dried separately to a constant weight at 70 ± 2^0C. It was multiplied by the number of branches to get leaf dry weight per tree. Below ground biomass of trees was calculated by using the guidelines of IPCC [12] and Cairns et al., [13].The tree carbon stock was estimated as:

Carbon stock = Biomass (above +below ground biomass) x 0.5 (IPCC default value)

The soil organic carbon stock (SOC) was determined using the formula given by Joa Carlos de et al., [14].

Soil organic carbon stock (t ha^{-1}) = Soil organic carbon (%) x depth (cm) x bulk density (g cm^{-3}).

Data were analyzed by using standard statistical procedure for split plot design Panse and Sukhatme [15] with the help of OPstat statistical package available online.

3) RESULTS AND DISCUSSION

Effect on poplar growth:

Diameter at breast height (DBH) and tree height

Poplar clones differed significantly for DBH and tree height in 2014-15 only (Table 1).

Table 1. DBH and height of Poplar tree as affected by poplar clones and wheat varieties at harvest of wheat

Treatment	Diameter at breast height (cm)		Tree height (m)	
	2013-14	2014-15	2013-14	2014-15
Poplar clone				
S_7C_8	7.94	11.67	7.50	9.35
G-48	6.89	11.56	6.54	9.14
W-39	6.90	11.80	6.59	9.30
Kranti	7.16	12.69	6.78	9.86
SEm+	0.33	0.12	0.28	0.082
CD 5%	NS	0.41	NS	0.29
Wheat variety				
DBW-17	7.46	12.03	6.97	9.53
PBW-502	7.12	11.71	6.82	9.33
UP-2748	7.09	12.04	6.75	9.38
HD-2967	7.22	11.93	6.87	9.41
SEm+	0.12	0.10	0.10	0.052
CD 5%	NS	NS	NS	NS

During 2013-14, clone S7C8 recorded the maximum DBH (7.94 cm) and tree height (7.50 m), followed by clone Kranti. During 2014-15, clone Kranti recorded significantly the highest DBH (12.69cm) and tree height (9.86m). Remaining clones were on par with each other. Toky et al., [16] and Puri et al., [8] also observed variations in DBH among different clones of *P. deltoides* and credited variation to the genetic makeup of the clones as all the clones were raised under similar soil and climatic conditions. Significant differences among clones for tree height were also observed by Dhillon et al., [17] and difference was attributed to the genetic makeup of the clones. Wheat varieties failed to cause significant variation in DBH and poplar tree height. Invariably, DBH and tree height of poplar tree were the maximum with the variety

DBW-17, except DBH in 2014-15, closely followed by HD-2967.

Tree biomass

All the components of tree biomass did not vary significantly among the clones and due association of wheat varieties except leaf biomass due to clones in 2013-14(Table 2). Clone Kranti recorded significantly higher leaf biomass than G-48 but remained at par with others. For other biomass components viz., branches, stem, roots and total; clone S_7C_8 recorded the maximum values followed by clone Kranti. Clone G-48 recorded the lowest values of all the components of tree biomass.

During 2014-15, stem, roots and total biomass varied significantly among the clones (Table 2). Clone Kranti produced significantly highest stem, roots and total biomass. Remaining clones did not differ significantly among themselves for stem, root and total biomass. Clone W-39 recorded the second highest values of stem, root and total biomass. The leaf and branch biomass was also the maximum with clone Kranti followed by the clone S7C8. Poplar clone Kranti recorded significantly the highest tree biomass (24.55 t/ha). Among remaining clone it was in the order of W-39 (20.95 t/ha) >S_7C_8 (20.93 t/ha)>G-48 (20.13 t/ha). The variable potential of different poplar clones to accumulate biomass may be ascribed to their genetic potential and are in line with Mishra et al., [9**].** The biomass of the tree stem is affected by the stem DBH and height as reported by Singh and Upadhyay [18] and Rizvi et al., [19].

Association of wheat varieties failed to bring significant variation in the poplar biomass during both the years. During both the years, the total tree biomass was the highest with variety DBW-17. In 2013-14 it was followed by variety HD-2967 (7.73 t/ha) and in 2014-15, by the variety UP-2748 (22.06 t/ha).

Effect on carbon sequestration

Carbon stock of wheat biomass differed significantly due to wheat varieties only (Table 3). Among poplar clones, S_7C_8 registered the highest C stock followed by Kranti during both the years. Wheat variety DBW-17 in 2013-14 and HD-2967 in 2014-15 recorded the highest carbon stock. Since, carbon stock in plant body is largely a function of biomass, so higher total biomass of these two varieties resulted in higher carbon accumulation. Further, these varieties did not differ significantly but were significantly superior to UP-2748 andPBW-502 during both the years.

Carbon stock in poplar tree biomass was affected significantly by poplar clones in 2014-15 only. Poplar clone S_7C_8 sequestered the maximum amount of carbon (4.25 t/ha) in 2013-14 followed by clone Kranti (3.87 t/ha). During 2014-15, clone Kranti recorded the maximum and significantly higher carbon stock. Remaining clones did not differ significantly for carbon stock in tree biomass. Swami and Mishra [20] also noted variability among poplar clones for carbon storage and found *P. deltoides* clones. Wheat varieties did not affect the carbon stock of poplar trees clones significantly during both the years. However, variety DBW-17 recorded the maximum amount of carbon in tree biomass during two years.

Carbon sequestered in the soil body was affected significantly only during 2014-15 by the poplar clones (Table 3). During 2013-14, the highest amount of carbon in soil was noted with the clone W-39 (49.32 t/ha) followed with the clone Kranti (49.29 t/ha). During 2014-15, under the clones Kranti and W-39, the soil carbon stock did not vary significantly. Under the clone G-48, the soil carbon stock was the lowest. Among wheat varieties, variety UP-2748 in 2013-14 and variety HD-2967 in 2014-15 recorded the maximum quantity of carbon in soil.

The total amount of carbon sequestered by the system as whole was affected significantly by the poplar clones in 2014-15 only (Table 3).

During both the year clone Kranti recorded the highest amount of carbon stock (57.14 t/ha in 2013-14 and 65.69 t/ha in 2014-15). In 2014-15, the total carbon sequestered with clone Kranti was significantly higher than other clones. The lowest amount of total carbon sequestered by the system was the lowest with the clone G-48. Variation in total carbon stock was largely related to the carbon stored in the trees. Amongst wheat varieties, the total carbon stock was noted with the variety DBW-17 during both the years and the lowest was with the variety PBW-502.

4) CONCLUSION

From the results of present study, it may be concluded that for higher growth and carbon stock in agroforestry system, poplar clones Kranti and S_7C_8 and wheat varieties DBW-17 and HD-2967 should be practices in 2-3 years old plantation in plains of northern India.

Table 2. Biomass accumulation (t/ha) in different parts of poplar trees as affected by poplar clones and wheat varieties.

Treatment	Leaf		Branches		Stem		Roots		Total	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
Poplar clone										
S_7C_8	1.75	2.33	0.83	2.57	4.83	12.41	1.56	3.63	8.97	20.93
G-48	1.36	2.24	0.80	2.29	3.35	12.11	1.16	3.49	6.67	20.13
W-39	1.55	2.21	0.79	2.37	3.40	12.73	1.21	3.64	6.95	20.95
Kranti	1.83	2.44	0.82	2.59	3.74	15.26	1.34	4.26	7.73	24.55
SEm+	0.08	0.09	0.03	0.08	0.44	0.31	0.10	0.08	0.59	0.45
CD 5%	0.29	NS	NS	NS	NS	1.10	NS	0.27	NS	1.57
Wheat variety										
DBW-17	1.59	2.37	0.81	2.46	4.15	13.44	1.38	3.84	8.97	22.11
PBW-502	1.63	2.23	0.80	2.42	3.68	12.52	1.28	3.62	6.67	20.78
UP-2748	1.66	2.31	0.81	2.48	3.66	13.44	1.29	3.82	6.95	22.06
HD-2967	1.62	2.31	0.82	2.45	3.83	13.10	1.32	3.75	7.73	21.61
SEm+	0.06	0.04	0.04	0.07	0.16	0.28	0.03	0.06	0.59	0.36
CD 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 3. Carbon stock (t/ha) in different components of poplar + wheat system as influenced by different poplar clones and wheat varieties.

Treatment	Wheat		Trees		Soil		Total	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
Poplar clone								
S_7C_8	4.05	3.71	4.25	10.30	47.94	48.19	56.24	62.20
G-48	3.88	3.69	3.60	10.23	48.87	48.01	56.35	61.93
W-39	3.90	3.67	3.47	10.47	49.32	49.33	56.69	63.47
Kranti	3.99	3.78	3.87	12.28	49.29	49.63	57.14	65.69
SEm±	0.088	0.035	0.29	0.22	0.74	0.32	0.084	0.36
CD 5%	NS	NS	NS	0.78	NS	1.13	NS	1.26
Wheat variety								
DBW-17	4.11	3.82	3.96	11.05	48.74	48.92	56.81	63.79
PBW-502	3.84	3.64	3.71	10.43	48.69	48.74	56.24	62.81
UP-2748	3.79	3.53	3.72	11.00	49.25	48.53	56.77	63.06
HD-2967	4.08	3.86	3.80	10.81	48.73	48.98	56.60	63.62
SEm±	0.068	0.046	0.08	0.18	0.46	0.38	0.48	0.35
CD 5%	0.20	0.14	NS	NS	NS	NS	NS	NS

ACKNOWLEDGEMENTS

The author is thankful to the Agro-Forestry Research Center of G.B.P.U.A. & T., Pantnagar for providing the area for carrying out successful field work.

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