BIOMASS PRODUCTION POTENTIAL AND NUTRIENT DYNAMICS OF *POPULUS DELTOIDES* UNDER HIGH DENSITY PLANTATIONS

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Introduction

The genus *Populus* belongs to family Salicaceae and has a unique ability to adjust and adapt to a wide range of sites. Poplar wood is white in colour of suitable density with an even texture. Its wood is easy to saw and work, has good carving quality indices and finishing qualities. Poplar wood is used in packing cases, hard boards, veneers, sports goods, pulpwood and poles. Besides this, Poplar wood is also used in matchbox industry for manufacturing match splints.

Biomass production is directly or indirectly related to the availability of plant nutrients besides the fast growth of the species. Due to high density plantations there is more pressure on the soil nutrients, as more number of trees are present on a unit area. So, it is also necessary to study the relationship between soil nutrients and biomass production. Also, some amount of nutrient is returned to the soil through leaf litter, hence the overall nutrient cycling studies can help to know about the nutrient balance and nutrient removal from the plantation area. The present study was carried out to investigate the above ground biomass production potential of *Populus deltoides* in relation to different population densities and component-wise distribution of biomass and plant nutrients cycling.

Material and Methods

The experimental site is located in the mid-hill zone of Himachal Pradesh at an elevation of 1200 m above mean sea level. The area lies between 30°51'N latitude and 76°11'E longitude and is a transitional zone between sub-tropical and moist temperate. On an average the annual rainfall varies from 1000-1400 mm, bulk of which is being received during monsoons i.e. July-September. The mean annual minimum and maximum temperatures were recorded as 13°C and 24.5°C respectively, whereas, mean annual temperature is 19°C.

The experimental was laid out in randomized block design in 1986 with three spacings viz. 60 cm x 60 cm (27,777 plants/ha), 90 cm x 90 cm (12,345 plants/ha) and 120 cm x 120 cm (6,944 plants/ha) and was maintained purely on rainfed conditions. Net plots size for each treatment was kept as 3.60 x 3.60 m which were replicated seven times. The plots were harvested in December, 1999, when the plantation was of 13 years.

For the above ground biomass estimation, 50 per cent of the total trees were felled in each replication using stratified mean tree technique (Art and Marks, 1971). All the trees were measured for diameter at breast height and total height. Fresh weight was recorded in the field for branches and bole. Representative samples of each component were collected for their dry weight estimation. Biomass of individual components was worked out by using formula :

$$\text{Dry matter} = \frac{\text{Dry weight of sample}}{\text{Fresh weight of sample}} \times \text{Total fresh weight}$$

Volume of the above ground biomass was estimated with the following formula :

$$V = \frac{f \times h \times \P d^2}{4}$$

Where,

V = Volume (m^3),
f = Form factor (2 h_1/3 h),
h = Total height (m),
h_1 = Height at which the diameter is half of dbh,
d = Diameter at breast height (cm),
g = Basal area and
¶ = Constant (22/7).

A representative composite samples of bole and branches were collected from each plot. Branch samples were collected from upper, middle and lower portion of the crown. Similarly, basal, middle and top portion of bole of each sample tree were sampled from different plots immediately after the harvesting. Litter (Leaf + branch twigs) was collected by laying two random quadrate of 1 m x 1 m in each plot and samples from each quadrate were collected and weighed in field. Composite samples of 100 g were taken for oven dry weight estimation and nutrient analysis. The plant samples collected were immediately weighed and brought to the laboratory in paper bags. All the samples were washed in series, first with tap water, then 0.1 N HCl followed by distilled water. The washed samples were allowed to dry in oven at 65 ± 5°C temperature till constant weight and subsequently samples were grounded in a willy mill and stored in butter paper bags for chemical analysis.

The estimation of total N in plant material was done using Kjeltec Auto 1030 Analyzer after digesting plant samples in concentrated H_2SO_4. For the determination of total P and K, 0.5 g of plant material was digested in 4 : 1 nitro perchloric acid (HNO_3 : $HClO_4$) mixture. In order to have a complete transfer of digested material, three washings of the digestion flask was given with distilled water and volume made to 100 ml. Total P in the digest was determined by Vanadomolybdate yellow orange colour method at 470 nm (Jackson, 1973), whereas total K in the extract was determined by Atomic Absorption Spectrophotometer (Z 6100).

Soil samples from varying depths 0-30 cm, 30-60 cm, were collected after harvesting for studying the depth-wise distribution of N,P,K organic carbon and soil pH. The soil samples were air dried, crushed and passed through 2 mm sieve and stored in cloth bags for chemical analysis. The chemical analysis was carried by the following methods : pH (Jackson, 1973), Organic carbon (Walkley and Black, 1934), Available nitrogen (Subbiah and Asija, 1956), Available phosphorus (Olsen *et al.*, 1954) and Available potassium (Merwin and Peech, 1951).

The entire data from the present investigations was put to statistical analysis in accordance with procedures outlined by Gomez and Gomez (1984).

Results and Discussion

Growth parameters and biomass distribution : The survival did not showed significant results with the variation in density (Table 1). However, maximum survival (73.29%) was observed at 120 cm x 120 cm spacing and minimum (67.06%) at 60 cm x 60 cm spacing. Tree height also showed non-significant results with varying density. However, it increased with increase in spacing. Tree height was maximum (11.71 m) at widest spacing and minimum (11.67 m) at closest spacing. Highest tree diameter, (8.53 cm) was observed at 120 cm x 120 cm spacing which differed significantly from 90 cm x 90 cm (7.18 cm) and 60 cm x 60 cm (5.54 cm) spacing. Differing significantly among spacing, maximum volume (363.4 m^3) was recorded at 60 cm x 60 cm spacing and minimum (238.2 cm^3) at 120 cm x 120 cm spacing. Following the trend of volume mean annual increment was highest (27.95 m^3/ha/yr) for 60 cm x 60 cm and lowest (18.32 m^3/ha/yr) for 120 cm x 120 cm spacing.

Survival of *Populus deltoides* was found to increase with decrease in plant density but this increase was not significant. This trend can be attributed to the less plant competition for space, light, nutrients and moisture at lower densities. Saralch (1994) and Temeche (1999) also reported the same trend of increase for *Eucalyptus tereticornis*. The significant increase in diameter with the corresponding decrease in density may be due to the less competition at lower densities. This significant increase in diameter is in accordance with the findings of Torvi *et al.* (1998) for *Pinus trecunumanii* and Bhardwaj *et al.* (2000) for *Eucalyptus tereticornis*. Volume and MAI computed on per hectare basis showed significant increase with increase in plant density. This increase can be attributed to the fact that there are more number of trees at higher density. The results are in line with the findings of Pandey (1987) for

Table 1

Effect of density on survival and dimensional growth in Populus deltoides

Growth parameters	Spacing (cm)			S.Em ±	CD 0.05
	60 x 60	90 x 90	120 x 120		
Survival (%)	67.03	69.83	73.29	4.44	NS
Height (cm)	11.67	11.69	11.71	0.73	NS
Diameter (mm)	5.54	7.18	8.53	0.07	0.16
Volume (m^3)	363.40	289.00	238.20	4.52	9.86
Mean Annual Increment (m^3/ha/yr)	27.95	22.23	18.32	0.34	0.75

Table 2

Effect of spacing on component-wise biomass distribution of Populus deltoides

Components	Spacing (cm)			S.E m ±	CD 0.05
	60 x 60	90 x 90	120 x 120		
Branch (kg/tree)	0.73	1.69	2.69	0.085	0.18
Branch (t/ha)	20.28 (9.29)	20.84 (11.36)	18.67 (12.87)	1.16	NS
Bole (kg/tree)	7.12	13.17	18.20	0.28	0.61
Bole (t/ha)	197.80 (90.71)	162.50 (88.64)	126.40 (87.13)	3.76	8.20
Total above ground biomass (kg/tree)	7.85	14.86	20.89	1.31	2.86
Total above ground biomass (t/ha)	218.08	183.34	145.07	4.49	9.80

Figures in parenthesis are per cent values of total above ground biomass.

Eucalyptus tereticornis and Torvi *et al.* (1998) for *Pinus trecunumanii*. The non-significant effect of plant density on height is in accordance with the findings of Xu and Chen (1994) for Poplar, Torvi *et al.* (1998) for *Pinus trecunumanii*.

The above ground biomass and its distribution to branch and bole is presented in Table 2. It is evident from the data that branch biomass differed significantly among the spacing. Branch biomass increased with increase in spacing. Maximum branch biomass (2.69 kg/tree) was recorded at 120 cm x 120 cm while minimum (0.73 kg/tree) at 60 cm x 60 cm spacing. On converting branch biomass on per hectare basis it showed non-significant results. The per cent contribution of branch biomass to total above ground biomass was 9.29, 11.36, 12.87 at 60 cm x 60 cm, 90 cm x 90 cm and 120 cm x 120 cm spacing respectively. Bole biomass showed significant variation with density. Maximum bole biomass (18.20 kg/tree and 126.40 t/ha) was recorded at 120 cm x 120 cm spacing. The proportion of bole biomass to total above ground biomass was 90.71, 88.64, 87.13 per cent at 60 cm x 60 cm, 90 cm x 90 cm and 120 cm x 120 cm spacing, respectively. Showing significant differences with density total above ground biomass was maximum (20.89 kg/tree and 145.07 t/ha) at 120 cm x 120 cm spacing and minimum (7.85 kg/tree and 218.08 t/ha) at 60 cm x 60 cm spacing.

The increase in bole biomass with the decrease in spacing may be attributed to the fact that the trees at lower density were having more diameter and number of branches per plant. These results are in accordance with the findings of Saralch (1994) and Temeche (1999) in *Eucalyptus tereticornis* plantation. Above ground biomass computed on hectare basis increased with the increase in plant density. This can be ascribed to difference in number of trees per ha which increased towards higher density. The results coincide with the findings of Armstrong *et al.* (1999) for three clones of Poplar and Saralch (1994) in *Eucalyptus tereticornis* plantations.

Table 3

Effect of planting density on macro-nutrient contents in Populus deltoides

Macro-nutrient (kg/ha)	Spacing (cm)			S.E m ±	CD 0.05
	60 x 60	90 x 90	120 x 120		
Nitrogen :					
Branch	156.10 (0.76)	143.80 (0.72)	137.30 (0.73)	6.23 (0.02)	13.60 (NS)
Bole	849.50 (0.44)	810.40 (0.49)	628.10 (0.49)	68.68 (0.03)	149.73 (NS)
Total biomass	1005.60	954.20	765.40	71.47	155.81
Phosphorous :					
Branch	1.76 (0.0087)	1.91 (0.0091)	1.98 (0.010)	0.91 (0.003)	NS
Bole	16.71 (0.0084)	13.68 (0.0084)	11.56 (0.0091)	0.90 (0.006)	1.97 (NS)
Total biomass	18.47	15.59	13.54	1.02	2.24
Potassium :					
Branch	121.40 (0.59)	99.32 (0.54)	104.60 (0.56)	14.34 (0.04)	NS
Bole	774.30 (0.39)	603.40 (0.37)	507.30 (0.40)	38.98 (0.03)	84.99 (NS)
Total biomass	895.70	702.72	611.90	43.84	95.58

Figures in the parenthesis are per cent values

Macro-nutrient content and their recycling : The data on per cent nutrient concentration at three spacing viz. 60 cm x 60 cm, 90 cm x 90 cm and 120 cm x 120 cm in tree components is presented in Table 3. Per cent nitrogen concentration in branch as well as bole was not influenced significantly by spacing. Nitrogen accumulation by branch was maximum (156.1 kg/ha) at 60 cm x 60 cm which was at par with 90 cm x 90 cm spacing (143.8 kg/ha) but differed significantly with spacing of 120 cm x 120 cm (137.3 kg/ha). Nitrogen content in bole also followed the same trend with maximum accumulation (849.5 kg/ha) at 60 cm x 60 cm and minimum (628.1 kg/ha) at 120 cm x 120 cm spacing. Total above ground nitrogen accumulation showed decreasing trends as the density decreased. It was highest (1005.6 kg/ha) at spacing of 60 cm x 60 cm and was lowest (765.4 kg/ha) at spacing of 120 cm x 120 cm.

Phosphorus concentration increased with the decrease in plant density. The phosphorus content in branch was maximum (0.01%) at spacing of 120 cm x 120 cm and was minimum (0.0087%) at spacing of 60 cm x 60 cm. However, all the three spacing were statistically at par. Similarly, bole phosphorus concentration was also non-significant for all the spacing. Branch phosphorus accumulation was non significant at different spacings. However, it registered 1.76, 1.91, 1.98 kg/ha for spacing or 60 cm x 60 cm, 90 cm x 90 cm and 120 cm x 120 cm respectively. Bole phosphorus accumulation differed significantly for all spacing, with maximum (16.71 kg/ha) for spacing of 60 cm x 60 cm and minimum (11.56 kg/ha) at spacing of 120 cm x 120 cm. Total above ground accumulation also showed significant differences among different spacing. Phosphorous accumulation was maximum

Table 4

Effect of spacing on depth-wise distribution of available macro-nutrients

Soil depth (cm)		Spacing (cm) 60 x 60	90 x 90	120 x 120	S.E m ±	CD 0.05
pH :	0-30	6.56	6.47	6.37	0.076	NS
	30-60	6.71	6.65	6.55	0.097	NS
	Mean	6.63	6.56	6.46		
OC (%) :	0-30	1.81	1.22	0.75	0.020	0.04
	30-60	1.06	0.86	0.44	0.012	0.03
	Mean	1.43	1.04	0.59		
N (kg/ha) :	0-30	273.50	301.00	340.60	4.03	8.78
	30-60	223.10	256.90	277.90	3.32	7.25
	Mean	248.30	278.95	309.25		
P (kg/ha) :	0-30	58.87	82.91	95.52	1.50	3.26
	30-60	49.01	59.20	73.22	1.79	3.92
	Mean	53.94	71.05	84.37		
K (kg/ha) :	0-30	236.10	256.60	312.20	1.80	3.93
	30-60	199.10	210.10	237.80	4.16	9.07
	Mean	217.60	233.35	275.00		

(18.47 kg/ha) for spacing 60 cm x 60 cm and was minimum (13.54 kg/ha) at spacing of 120 cm x 120 cm. Spacings 90 cm x 90 cm and 120 cm x 120 cm were at par with each other.

Potassium content in branch was maximum (0.59 per cent) at 60 cm x 60 cm spacing and was minimum (0.54 per cent) at 90 cm x 90 cm spacing while potassium content in bole was maximum (0.40 per cent) at 60 cm x 60 cm spacing and was minimum (0.37 per cent) at spacing of 90 cm x 90 cm. Potassium accumulation in bole was significantly affected by spacing. It was maximum (774.3 kg/ha) at spacing 60 cm x 60 cm and was minimum (507.3 kg/ha) at spacing of 120 cm x 120 cm.

N, P and K retention in branch, bole and above ground biomass showed decreasing trend with increase in spacing. This can be attributed to the fact that there was more branch, bole and above ground biomass production in close spacing as compared to the wider spacing. These results were line with the findings of Temeche (1999) and Bhardwaj *et al.* (2000) in *Eucalyptus tereticornis* plantation.

The chemical characteristics of the soil pH, organic carbon, nitrogen, phosphorus, potassium under *Populus deltoides* plantation are presented in

Table 4. There is no significant difference in pH values at 0-30 cm and 30-60 cm depths of soil. However, soil pH showed increased trend with increasing soil depth at all plant densities. Organic carbon content in the soil at both the depths (0-30 cm, 30-60 cm) increased significantly with reduction in spacing. The data in Table 4 revealed than increase in plant density had significant negative effect on the available nitrogen content in soil at both soil depths. There was a decreasing trend in available nitrogen content with increase in soil depth. The data on amount of available phosphorus revealed that there was significant difference of available phosphorus among different spacings at both the depths. There was decreasing trend in available phosphorus content with increase in soil depth. Available potassium decreased with the increase in plant population, while with increase in soil depth, there was decrease in available potassium content at all plant densities. At 0-30 cm depth, it was maximum (312.2 kg/ha) at 120 cm x 120 cm spacing and was minimum (236.1 kg/ha) 60 cm x 60 cm spacing. At 30-60 cm depth it was recorded highest (237.8 kg/ha) at 120 cm x 120 cm and was lowest (199.1 kg/ha) at 60 cm x 60 cm spacing.

The increase in pH with depth could be ascribed to substantial addition of organic matter at higher density than lower one on the surface and less organic matter addition due to root litter and increase in clay content of the soil, respectively. The findings are in line with the findings of Soni (1991), Sharma (1991), Kaushal (1992), Saralch (1994) and Das *et al.* (1996). Organic carbon content decreased with decrease in density and increase in soil depth. These results are in conformity with the findings of Bisht *et al.* (1989), Soni (1991), Sharma and Singh (1991), Sharma (1991), Jha and Chhimwal (1993) and Saralch (1994). The significant decrease for N, P and K with the increase in plant number may be due to more nutrient uptake per unit area since more roots exerted on the nutrient absorption in the soil in comparison to lower plant number. The decrease in available macro-nutrients was also observed with increase in soil depth irrespective of planting density, this can be attributed to deep rooted nature

Table 5

Effect of biomass on macro-nutrient cycling in Populus deltoides

Spacing	Nutrients (kg/ha)								
	Nitrogen			Phosphorous			Potassium		
	60 x 60 cm	90 x 90 cm	120 x 120 cm	60 x 60 cm	90 x 90 cm	120 x 120 cm	60 x 60 cm	90 x 90 cm	120 x 120 cm
Total above ground accumulation	1005.60	954.20	765.40	18.47	15.59	13.54	895.70	702.72	611.90
Release through litter fall	288.80	261.20	240.90	15.28	13.27	12.88	127.50	120.20	107.20
Total uptake	1294.40	1215.40	1006.30	33.75	28.86	26.42	1023.20	822.92	719.10

of trees. These results are on line with the findings of Banerjee and Nath (1991) for forest soils of Sikkim, Sharma and Singh (1991) for soils of Kinnaur, Malik (1992) for Chir pine forests of Solan District, Kaushal (1992) for Deodar forest soils of Kinnaur.

The balance of macro-nutrients N, P and K in 13 years old *Populus deltoides* plantation has been presented in Table 5. It is evident from the table that both accumulation of nutrients and its uptake showed increasing trends for macro-nutrients (N, P, K) kg/ha, with the increase in plant population. The total amount of nitrogen retained (branch + bole) was highest (1005.6 kg/ha) at 60 cm x 60 cm followed by 954.2 kg/ha at 90 cm x 90 cm and least (765.4 kg/ha) at 120 cm x 120 cm spacing. Whereas, P and K had values to the tune of 18.47 kg/ha and 895.7 kg/ha of 60 cm x 60 cm spacing, 15.59 kg/ha and 702.72 kg/ha at 90 cm x 90 cm spacing and 13.54 kg/ha and 611.9 kg/ha at 120 cm x 120 cm spacing, respectively. Total above ground uptake (retained + returned through litterfall) was highest at 60 cm x 60 cm spacing with respective values of N, P and K 1294.9, 33.75, 1023.2 kg/ha and least at 120 cm x *120 cm spacing having* values of 1006.3, 26.42 and 719.1 kg/ha, respectively.

SUMMARY

The experiment on *Populus deltoides* was laid out in randomised block design with three densities viz 60 cm x 60 cm (27,777 plants/ha), 90 cm x 90 cm (12,345 plants/ha) and 120 cm x 120 cm (6,944 plants/ha) under rainfed conditions in mid hill zone of Himachal Pradesh. The plantation harvested after 13 years, produced maximum biomass (218.08t/ha) in the closest spacing of 60 cm x 60 cm for which the bole contributed 90.71 per cent of the total above ground biomass accumulation. The nutrient accumulation in the biomass also differed with the density. The maximum nutrients were present in the closest spacing. It was further observed that organic carbon content in the soil decreases with the decrease in density. Conversely, an increase was observed in nitrogen, phosphorous and potassium content of soil with the increase in spacing. Study reveals that accumulation of nutrients in the biomass is higher in 60 cm x 60 cm spacing whereas, the nutrient return through litterfall was less as compared to the total uptake which created nutrient deficit in the soil.

अधिक घनत्व वाले रोपवनों में *पोपुलस डेल्टायडिस* की जैवपुंज उत्पादन क्षमता तो पोष्याहारो की गतिकी

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सारांश

पोपुलस डेल्टायडिस पर यह संपरीक्षण हिमाचल प्रदेश के मध्य पहाड़ी क्षेत्र की वर्षापोषित दशाओं में तीन सघनताएं अर्थात 60 x 60 सेमी^{2} (27,777 पादप/हेक्टे०) 90 x 90 सेमी^{2} (12,345 पादप/हेक्टे०) और 120 x 120 सेमी^{2} (6,944 पादप/हेक्टे०) लेकर या दृच्छिक खण्ड आकल्प विधि से किया गया । रोपवन की कटाई 13 वर्ष बाद की गई जिससे सर्वाधिक जैवपुंज प्राप्ति (218.08 टन/हेक्टे०) कम फासला बीच में 60 x 60 सेमी^{2}, छोड़ने पर मिली जिसमें भूमि से ऊपर संचित हुए कुल जैवपुंज में तीनों का योगदान 90.71 प्रतिशत रहा । जैवपुंज में संचित हुए परिमाण की सम्पन्नता में भी अन्तर पाया गया । अधिकतम पोष्याहार पादपों को सर्वाधिक निकट लगाने पर उनमें संचित हुआ । इसके अतिरिक्त यह भी देखा गया कि हटाए जाने पर मृदा के जैव कार्बन में भी घटत आ जाती है । इसके प्रतिकूल, बीच का फासला बढ़ाए जाने पर मृदा के नाइट्रोजन, फास्फोरस और पोटाशियम में वृद्धि होती है । इस अध्ययन से पता लगा कि 60 x 60

सेमी² फासला पादपों के मध्य छोड़ा जाने पर जैवपुंज में पोष्याहारों का संचयन अधिक होता है जबकि मृदा से ग्रहीत कुल पोष्याहारों की तुलना में पर्णास्तरण गिरने से मृदा में पोष्याहारों की वापसी कम होती है जिससे मृदा के पोष्याहारों में कमी आती है ।

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