THE POTENTIAL OF *POPULUS DELTOIDES* IN THE SUB-HUMID TROPICS OF CENTRAL INDIA : SURVIVAL, GROWTH AND PRODUCTIVITY

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Introduction

Populus deltoides Bartr., a native of North America is one of the fast growing tree species. The high biomass and productivity of this species has received worldwide attention. Its merchantable biomass is largely used in manufacturing matches, veneer, fibre-board, plywood and paper pulp. It was successfully introduced in Northern India above 28°N latitude in Tarai region in early 1960s. Presently many selections of *P. deltoides* are grown in the States of Punjab, Haryana, Uttar Pradesh, Uttaranchal and Himachal Pradesh. The species has proved as an excellent choice of farming communities under agroforestry/ farm forestry practices in Northern India. In Punjab, a production of 46.9 $m^3ha^{-1}yr^{-1}$ has been achieved through intensive management practices as compared 0.7 $m^3ha^{-1}yr^{-1}$ estimated growth rates of forests in India (Dhanda, 1999). Because of its fast growth, easy propagation and ability to provide substantial wood on a short rotation period, the need is to introduce it in other parts of the country. For this intensive experiments on screening and evaluation are required for identifying promising clones suitable for that region. Although *P. deltoides* in India is grown above 28°N latitude, there may be some clones which can come up very well even below this latitude (Gogate and Joshi, 1992). In this context an attempt has been made to introduce and evaluate different clones of *P. deltoides* in sub-humid tropics of Central India. Studies related to clonal variation in biomass production and net primary productivity is also reported in this paper.

Material and Methods

Study Area : The present study was conducted at Raipur situated at 21°12'N latitude and 81°36'E longitude, representing South-East of Central India in the Chhattisgarh State. It has three distinct geological formations viz., Bijapur-Cuddapah, Dharwar and Archean. Lithologically it is divided in to seven areas, namely Raipur shale and limestone, Khairagarh sandstone, Gunderdehi shale, Cadappahas charmur limestone, Chandrapur sandstone grit, Dharwar rocks, Granite and gneiss. The topography of the study area is plain to undulating slopes with a slope of 1-2 per cent. The study area is characterised by vertisol soils which are greyish black, medium to very deep in

nature. The important physico-chemical characters of the soil at the study site are given in Table 1. Of the total annual rainfall (1260 mm), about 80 per cent is usually received during monsoon season from June to October. The average number of rainy days varies from 65 to 79. The mean monthly maximum temperature ranges from 27.3°C in December to 42.3°C in May and mean monthly minimum temperature varies from 13.2°C in December to 28.3°C in May. The monthly mean relative humidity varies from 82 per cent in July to 29 per cent in May. The mean annual weather data prevailing during the last five years of study is given in Table 2.

Table 1

Important physical and chemical properties of soil in the study area

Physical properties	Value
Mechanical composition (%) :	
Sand	20-30
Silt	20-30
Clay	>45
Bulk density (g/ml)	1.30-1.60
Soil depth (cm)	≥ 150
Infiltration rate (cm/hr)	2.0-2.5
Field capacity (cm)	37.0
Wilting point (cm)	20.2
Available water (cm)	16.8
Chemical properties	**Value**
pH	7.4-7.6
Electrical conductivity (dSm^{-1})	0.3
Organic carbon (%)	0.67
C.E.C. (cmol)(+)/kg)	38.4-40.8
Exchangeable cations	
(i) Calcium	27.0-29.0
(ii) Magnesium	7.8-9.0
(iii) Potassium	0.9-1.1
(iv) Sodium	0.5-0.7

Germplasm collection and establishment of nursery : Germplasm comprising of 106 clones from different parts of the Northern India were collection as cuttings in January and planted in departmental nursery. The cuttings were collected from Punjab Agricultural University (PAU), Ludhiana (Punjab); University of Horticulture and Forestry (UHF), Solan (H.P.), Haryana Agricultural University (HAU), Hisar (Haryana); G.B. Pant Agricultural University (GBPAU), Pantnagar and Forest Research Institute (FRI), Dehra Dun (Uttaranchal). The clones collected from different geographical sources are given in Table 3.

Cuttings of 22 ± 2.5 cm long and 1.5 ± 0.5 cm diameter having at least 4-5 buds were prepared and planted in nursery beds. Prior to planting, cuttings are drenched first with Aldrin (2%) and then treated with Emisan (0.1%). Cuttings were planted in flat beds comprising of soil, sand and compost (mixed in equal ratio by weight) at 60 cm x 60 cm distances. Beds were also drenched with BHC (10%) to protect then cuttings from termite attack. Cuttings were irrigated weekly during winter (January-February) and at 3 day intervals in summer (March-June), while no irrigation was given during monsoon (July-October) season except during dry spells. Cuttings were grown in nursery beds for one year and replanted for evaluation during the second year.

Clones were evaluated in terms of mortality and morphological growth characters for successive two years in the nursery. The best performing 19 clones were selected for field evaluation trial. The

Table 2

Meteorological data of study site

Year	Temperature (°C)		Total annual rainfall (mm)	Relative humidity (%)
	Max.	Min.		
1994	31.1	18.4	1688.2	71.76
1995	32.1	19.7	1188.7	81.66
1996	33.2	19.6	1122.8	69.66
1997	32.2	19.6	1208.4	79.90
1998	*32.3*	*20.6*	*1088.0*	*83.41*

Table 3

Germplasm collection sources of Populus deltoides clones

Source	State	Latitude	Longitude	No. of clones	Cuttings planted/ clone
PAU, Ludhiana	Punjab	30°54'N	75°48'E	68	100
HAU, Hissar	Haryana	29°12'N	75°42'E	30	90
GBPAU, Pantnagar	Uttaranchal	29°06'N	79°39'E	4	125
YSPUHF, Solan	Himachal Pradesh	29°10'N	77°35'E	5	100
FRI, Dehra Dun	Uttaranchal	30°18'N	78°06'E	21	125

transplanting of stecklings was done by Entire Transplant (ETP) method in the month of January. One-year-old ETPs with naked roots (root was cut at 25 cm depth) were planted in the winter month of January in a Randomised Block Design (RBD) with three replications of each clone. Thus, a total of 48 ETPs were transplanted for each clone at a spacing of 4 m x 4 m. Each plant was fertilized with 50 g of single superphosphate and 25 g of muriate of potash. Nitrogen in the form of diammonium phosphate (DAP) was given @ 40 g/plant in two split doses (last week of June and September).

Morphological growth characters of trees viz., collar diameter, diameter at least height (DBH), tree height, crown diameter, crown length, number of branches, mean length of branches, etc. were recorded annually. Four sample trees in the center of each plot were measured and the mean values were analysed statistically by analysis of variance (Steel and Torie, 1980). Duncan's multiple range test used to separate means wherever analysis of variance was significant (Duncan, 1955).

The tree biomass of different clones were estimated using a non-harvest

technique. Allometric regression equations developed by Negi and Tandon (1997) were used for the estimation of component- wise above ground biomass. Different equations employed for biomass estimation are given in Table 4. The root biomass was computed using root-shoot ratio as determined by Puri *et al.* (1994). Annual increment of height and diameter at breast height was used for the computation of component wise biomass production. Litter fall was measured by using litter traps at bimonthly intervals. Net Primary Productivity (NPP) of different clones was determined by adding the values of annual increments in biomass of different components (stem, branches, leaves and root) and total annual litterfall.

Results

Nursery evaluation : Among 106 clones of *Populus deltoides* planted from different geographical sources, a few clones (1293/84, 2500, C5M2 and M187) did not survive in the nursery (Table 5). However, the majority of the clones survived but their survival percentage showed significant variation. For example, PD-I, PD-48, PD-1N, 90-II and N-1 clones showed 100 per cent survival, while 65-2, 80-I, 134/86, 80-0, 65/27, G3, G48, D121 and S7C1 clones showed more than 90 per cent survival. On the basis of growth in height and root collar diameter, the clones were categorized into 4 groups (Table 5). Group I represents vigorous growing clones with root collar diameters more than 2.5 cm and heights above 3.5 m, while group IV constitutes very slow growing clones with root collar diameters less than 1 cm and heights below 1.5m. Only 19 clones viz., PD-I, PD-48, PD-1N, 90-II, N-1, 65-2, 80-I, 40-2, 88-0, 65/27, G3, G48, D121, S7C1, 90-I, 13/86, L-80, 14-2, 134/86 were found to be vigorous in growth (Table 5). Interestingly all those clones which showed high percentages (>85) of survival were present in group I. These best performing nineteen clones of group I were further evaluated in the field trial.

Field evaluation : Analysis of variance of the 19 clones of two years old plantation indicated that significant differences were observed in growth traits viz., root collar diameter, DBH, height and number of branches; while leaf area was found to be non-significant (Table 6). Survival ranged from 40 to 100 per cent in different clones, highest survival was observed 65/27 clone while lowest in 80-I. Growth rate in terms of collar diameter, DBH, height and

Table 4

Allometric equations for biomass estimation in Populus deltoides

Component	Equation	r^2
Bole	$Y = 0.01587.X^{2.97897}$	0.99
Bark	$Y = 0.0054.X^{2.68283}$	0.99
Leaf	$Y = 0.0468.X^{1.67912}$	0.95
Branch	$Y = 0.1253.X^{1.4099}$	0.84
Total aboveground	$Y = 0.00985.X^{3.1854}$	0.98

Note : Y is component biomass in kg and X is DBH in cm

Table 5

Initial screening of Populus deltoides clones under nursery conditions on the basis of growth rate

Growth	Clone	Root collar diameter (cm)	Mean root collar diameter (cm)	Height (m)	Mean height (m)	Survival range (%)
Vigorous	PD-I, PD-48, PD-1N, 90-II, N-1, 65-2, 80-I, 40-2, 88-0, 65/27, G3, G48, D121, S7C1, 90-I, 13/86, L-80, 14-2, 134/86	>2.5	3.0	>3.5	4.0	85-100
Semi-vigorous	WSL-7, S7C8, D-4, S748/111, L-182/84 L-39/84, ST 72, CP 82-2-2, 22/86, CP 82-1-7, A24, PD-94-38-44, L-71/84, L-156/84, S7C2, WSL-4, CP-82-5-4, WSL-62, S7C7	1.5-2.5	2.0	2.5-3.5	3.0	60-80
Slow	WSL-57, L-51/84, 109/86, L-154/84, L-162/84, WSL-37, ONDA, L-75/84, S7C4, L274/84, L142/84, L-49/84, WSL-II, I-214, ECO-28, WSL-31, LIC-73/52, LI-79/84, 3650, 69/55, 188/89, 62/84, 63/51, I-58, I-488	1-1.5	1.25	1.5-2.5	2.0	30-60
Very slow	GUARDI, CP-82-2-3, CP-82-5-12, 3/67, CP-82-6-4, D-67, CP-82-6-3, CIMA, BL Costa 420, Fredo, A13, S. Martino, CP-82-5-1, CP-82-5-17, L 12/82, CP-82-1-9, D-29, S7C20, CP-82-6-8, CP-82-4-12, Triplo, Spido, CH-2-8, 98-I, Luisaavanzo, 110702, 113324, L-171/81, CP 82-5-16, CP-82-4-1, CP-82-5-19, 4/66, 104, L -200/89, L -313/85, 2/56, 260/85, WSL-38, S748/11	<1	0.5	<1.5	1.0	5-30

Note : Clones 1293/84, 2500, C5M2 and M187 showed 100 per cent mortality

number of branches were recorded higher in 65/27, D121, G3, G48 and S7C1 clones as compared to other clones which showed relatively poor growth. On the basis of growth and survival after two years of plantation, the order of ranking of best five clones was 65/27 > G3 > D121 > G48 > S7C1.

Similarly in four year old plantation a significant variation in growth was observed between different clones (Table 7). The variation in growth within a clone were ranked based on giving scores to different parameters studied. The highest score is given to a parameter showing minimum value and lowest to a character with

Table 6

Survival and growth characteristics of some promising clones of Populus deltoides (2 year old) planted in the field

Clone	Survival	Root collar diameter (cm)	DBH (cm)	Height (m)	No. of branches	Leaf area (cm^2)
G3	95	4.63a	3.82ab	4.85a	12.9b	394.2
65/27	100	4.91a	4.16a	5.20a	15.4a	317.1
D121	80	4.38ab	3.98ab	4.83a	14.5a	394.2
G48	90	4.25ab	3.80ab	4.71a	16.2a	296.5
S7C1	80	3.98b	3.41b	4.68a	10.4c	228.5
PD-I	60	3.01c	2.45c	3.56c	08.1d	296.0
88-0	70	2.51d	1.55d	3.46c	06.4e	214.0
90-II	80	3.02c	1.85d	4.15b	04.5f	255.0
90-I	90	2.85c	2.11cd	4.01b	05.2ef	201.1
13/86	55	2.90c	1.73d	3.58c	03.1f	205.2
80-I	40	3.10c	1.78d	3.78c	02.2g	229.2
L-80	60	2.81d	2.11c	4.01b	04.8f	281.5
14-2	50	3.32c	1.85d	4.12b	06.2e	232.5
N-1	45	3.35c	4.68a	3.56c	08.5d	235.6
65-2	52	3.44c	2.25cd	4.11b	03.6f	238.2
PD-48	61	3.42c	2.75c	4.01b	8.14d	226.5
40-2	49	3.30c	1.73d	3.56c	5.30ef	236.2
134/86	52	3.44c	2.80c	4.05b	4.00f	205.2
PD-1N	58	3.42c	2.75c	4.18b	2.80g	218.2
CD at 5%		0.43	0.45	0.54	1.54	NS

Note : NS = Non-significant;
Figures followed by the same letter within a column do not differ significantly

maximum value. Scoring and ranking so obtained on the basis of parameter studied is given in Table 7. It is evident from the table that the 65/27 clone was the best with regard to growth performance. On the basis of scores, the clones can be categorized in to 4 groups. Group I represent vigorous growing clones (65/27, S7C1, G48, G3 and D121), while clones ranked 6 to 12 form group II, and clones ranked 16 to 19 (88-0, 14-2, 90-II, L-80) form group IV, the most slow growing group. The best five growing clones after 4 years of plantation were the same as that obtained in 2 year old plantation, but the order of ranking changed amongst them (the order of ranking after four year was 65/27 > S7C1 > G48 > G3 > D121).

Estimated above ground and below ground biomass of four year old clonal plantation are presented in Table 8. A maximum total biomass of 54.27 MT ha^{-1} was observed in the 65/27 clone which was

Table 7

Growth characteristics ranking and scoring of four year old Populus deltoides planted in the field

Treatment	DBH (cm)	Height (m)	Crown length (m)	Crown width (m)	Branch length (m)	Rank
G3	12.67a	11.67a	8.45ab	2.45b	2.27a	4
65/27	15.40a	13.67a	10.58a	2.53b	2.22a	1
D121	13.80a	10.75ab	8.13ab	2.07b	2.17a	5
G-48	14.23a	11.85a	8.58ab	2.55b	2.32a	3
S7C1	12.17a	11.93a	9.00a	2.63b	2.44a	2
PD-I	12.17a	09.40b	3.50c	2.33b	1.72ab	11
88-0	06.62b	06.32bc	3.43c	2.00c	2.01a	16
90-II	06.07b	06.73bc	3.57c	1.70c	1.27ab	18
90-I	09.93ab	07.80bc	4.17bc	2.33b	2.17a	12
13/86	09.93ab	09.60b	5.67bc	1.80c	1.87a	10
80-I	12.27a	08.75b	5.56bc	3.51a	1.82ab	6
L-80	04.87c	05.07c	2.40c	1.67c	0.93b	19
14-2	07.53b	06.50bc	2.90c	2.00c	1.43ab	17
N-1	08.13b	07.93b	4.18bc	2.58b	2.21a	8
65-2	13.40c	09.73b	6.23b	2.17b	1.70ab	7
PD-48	09.40ab	08.10b	5.17bc	1.80c	1.50ab	14
40-2	12.67b	09.40b	3.57c	2.50b	1.67ab	9
134/86	06.80b	08.25b	4.78bc	1.45c	1.80ab	15
PD-1N	10.00ab	06.73bc	3.40c	2.27b	1.70ab	13
SEm±	01.21	0.68	0.57	0.25	0.21	
CD at 5%	03.44	1.93	1.63	0.71	0.60	

Note : Figures followed by the same letter within a column do not differ significantly

more than 15 times higher as compared to the L-80 clone. Stemwood in different clones varied from 33.7 to 62.2 per cent of the total biomass followed by coarse roots (16.5-28.0%), branches (7.4-23.7%), bark (7.5-12.9%) and leaves (5.3-10.3%). The proportion of stemwood was maximum in S7C1 clone, while it was minimum in 90-I clone. The biomass variation in different components was found to be significant in the nineteen clones tested. The above ground biomass in different clones varied from 2.79 to 43.77 MT ha^{-1}, while that of coarse roots it was 0.67 to 10.5 MT ha^{-1} (Table 8).

Net primary productivity (NPP) is computed as the total biomass production of above-ground and below-ground components and also on the amount of litter produced (Table 9). It is evident that NPP for different components and of the whole tree varied significantly between different clones planted. For all the

Table 8

Standing biomass (MT ha^{-1}) four year old Populus deltoides clones under field conditions

Clone	Stem	Bark	Leaf	Branch	Above ground	Coarse root	Total biomass
G3	20.79a	3.30a	2.17a	3.29a	29.55a	7.09a	36.64a
65/27	32.12a	4.87a	2.75a	4.03a	43.77a	10.50a	54.27a
D121	24.85a	3.88a	2.40a	3.60a	34.73a	8.34a	43.07a
G48	27.53a	4.25a	2.54as	3.76a	38.08a	9.14a	47.22a
S7C1	23.04a	2.85ab	1.96ab	3.01ab	30.86a	6.13ab	36.99a
PD-I	17.46ab	2.82ab	1.95ab	3.01ab	25.24ab	6.06ab	31.30ab
88-0	04.07c	0.73c	0.76c	1.31b	06.87b	1.65b	08.52c
90-II	02.79c	0.52c	0.64c	1.15b	05.10b	1.22b	06.32c
90-I	05.02c	1.92b	1.46b	2.31ab	10.71b	4.17ab	14.88bc
13/86	09.27b	1.60b	1.38b	2.25ab	14.50b	3.48b	17.98bc
80-I	17.6ab	2.84ab	1.97ab	3.04a	25.45ab	6.11a	31.56ab
L80	01.28c	0.26c	0.43c	0.82c	02.79c	0.67c	03.46c
14-2	06.01c	1.03c	0.94c	1.58b	09.56b	2.30b	11.86bc
N-1	05.47c	0.98c	1.00c	1.70b	09.15b	2.20b	11.35bc
65-2	22.91a	3.58a	2.29a	3.46a	32.24a	7.74a	39.98a
PD-48	07.86b	1.38c	1.26b	2.07b	12.57b	3.02b	15.59bc
40-2	21.22a	3.33a	2.12a	3.22a	29.89a	7.17a	37.06a
134/86	03.13c	0.60c	0.74c	1.30b	05.77b	1.38b	07.15c
PD-1N	10.44b	1.76b	1.42b	2.28ab	15.90b	3.82b	19.72b
CD at 5%	12.51	1.60	0.78	0.94	14.25	3.42	17.67

Note : Figures followed by the same letter within a column do not differ significantly

components studied the maximum was in D121 clone followed by 65/27 clone. Total net primary productivity was 20 times higher in D121 clones as compared to L-80 clone. Litter fall in different clones varied from 2.34 to 0.12 MT ha^{-1} yr^{-1}.

Discussion

The environmental degradation and energy crisis have prompted a renewed interest in the productivity potential of short rotation plantations for afforestation and agroforestry purposes. *Populus deltoides*, a fast growing exotic, has been successfully introduced in North India. Among the many clones tested only a few showed good growth and many clones failed to establish in north India, especially below 28°N latitude (Lodhiyal and Lodhiyal, 1997). The present study attempted to introduce different clones of *P. deltoides* in the sub-humid tropics of Central India at 21°N latitude. Among the 106 clones tested, only 19 clones showed higher growth (DBH and height) and survival in nursery and field sites (Tables 5 and 6). As in many earlier studies (Kaul *et al.*, 1983; Tiwari, 1993;

Table 9

Net Primary Productivity of 19 clones of Populus deltoides under field trial after 4 years of planting (MT ha^{-1})

Clone	Stem	Branch	Bark	Leaf	Above-ground	Root	Litter	Total NPP
G3	06.75ab	0.91a	1.06ab	0.63a	9.35ab	2.25ab	1.39ab	12.99ab
65/27	11.86a	1.19a	1.75a	0.70a	15.5a	3.76a	2.33a	21.59a
D121	11.90a	1.22a	1.77a	0.88a	15.77a	3.78a	2.34a	21.88a
G48	09.00a	1.06a	1.38a	0.75a	12.19a	2.92a	1.81ab	16.92a
S7C1	05.77ab	0.84a	0.92ab	0.58b	08.11b	1.95ab	1.21ab	11.27ab
PD-I	05.77ab	0.91a	0.93ab	0.61a	08.22ab	1.97ab	1.22ab	11.41ab
88-0	01.35b	0.38b	0.22b	0.23b	02.18b	0.58b	0.33b	03.09c
90-II	00.91c	0.32b	0.17b	0.19b	01.59b	0.38b	0.23b	02.20c
90-I	03.87ab	0.69ab	0.63ab	0.45ab	05.64ab	1.35ab	0.84b	07.83b
13/86	03.08b	0.69ab	0.53ab	0.44ab	04.74b	1.13b	0.70b	06.57b
80-I	05.85ab	0.95a	0.94ab	0.63a	08.37ab	2.01ab	1.24ab	11.62ab
L80	00.40b	0.19b	0.08b	0.11b	00.78c	0.19b	0.12b	01.09c
14-2	01.98b	0.46ab	0.34b	0.29b	03.07b	0.74b	0.46b	04.27c
N-1	01.76b	0.45ab	0.31b	0.28b	02.80b	0.67b	0.42b	03.89c
65-2	07.60ab	1.04a	1.19a	0.73ab	10.56a	2.54a	1.58a	14.68a
PD-48	02.55b	0.56ab	0.44b	0.36b	03.91b	0.94b	0.57b	05.43c
40-2	07.36ab	0.74ab	1.10ab	0.68a	09.88ab	2.37ab	1.47ab	13.72a
134/86	00.97c	0.46ab	0.16b	0.19b	01.78b	0.40b	0.25b	02.43c
PD-IN	03.42ab	0.64ab	0.54b	0.42b	05.02ab	1.21ab	0.75b	06.98b
CD at 5%	04.44	0.39	0.63	0.30	05.73	1.37	0.85	07.96

Note : Figures followed by the same letter within a column do not differ significantly

Lodhiyal and Lodhiyal, 1997), the present study also reveals clonal variation in growth, biomass and productivity in *P. deltoides*. Sidhu (1996) evaluated 16 Poplar clones at Ludhiana (30°N latitude) and reported that G3, G48, S7C1, S7C8, S7C20 clones showed higher collar diameter and height as compared to A13, ST-67, S7C4, ST-67, CIMA and Martini clones. In another study at Lalkuan (30°N latitude) among different clones tested (S7C1, S7C4, S7C8, S7C15 and S7C20) only S7C20 clone was found to be fast growing (Chaturvedi, 1982). Interestingly in the present study S7C1 clone showed best growth while other clones showed poor growth and survival.

Katoch and Brar (1983) in Maharashtra (21°6'N latitude) found that the G3 clone showed better growth under nursery conditions as compared to the IC group of clones. Sharma *et al.* (1991) reported higher growth in D66 and S7C8 clones as compared to G3, G48 and D121 clones at Dehra Dun (30°18'N latitude). Toky *et al.* (1996) found that in Hisar

Table 10

Comparative account of distribution of above-ground biomass of Poplar

Species	Location	Age (yr)	Density (ha^{-1})	Above-ground biomass (MT ha^{-1})	Authors
Populus deltoides	India (Tarai)	1-4	666	7.4-89.3	Lodhiyal and Lodhiyal, 1997
P. deltoides	India (Tarai)	5-8	400	67.4-134.3	Lodhiyal *et al.*, 1995
P. tremuloides	North Central	8	-	25.4	Ruark and Bokheim, 1988
P. tremuloides	Wisconsin Canada	5	-	8.3-34.8	Wang *et al.*, 1995
P. deltoides	Alabama	8	-	89.7	Carter and White, 1971
P. deltoides	India (Dehra Dun)	5	-	22.5	Negi and Tandon, 1997
P. deltoides (Clone IC)	India	10	500	105.4	Singh, 1989
P. deltoides	India	14	-	44.5	Raizada and Srivastava, 1989
P. deltoides	USA	16	-	133.7	Shelton *et al.*, 1982
P. deltoides	India (Hisar)	9	208-2250	71.5-251.5	Puri *et al.*, 1994
P. deltoides (agri-silviculture)	India (Raipur)	4	666	2.79-43.77	Present study

(29°10'N latitude) the CP-82 group of clones showed better growth in comparison to G3 and G48 clones in nursery and field conditions. These and the present studies strengthen the view that growth and survival of different clones can be mainly ascribed to genetic potential and there is a need to test more genotypes (Thomas *et al.*, 1997; Dang *et al.*, 1994). It is pertinent to mention that the growth in terms of root collar diameter, DBH and height of the selected 19 clones under field conditions was comparable to the growth of *Populus deltoides* in other parts of India (Puri *et al.*, 1994; Sidhu, 1996; Toky *et al.*, 1996).

Growth in the 4 year old plantation was comparable to growth recorded in same age plantation at Dehra Dun (30°18'N latitude) by Negi and Tandon (1997). For example, DBH ranged between 5.8 to 14.5 cm in Poplar plantation at Dehra Dun while it ranged from 4.87 to 15.40 cm in the present study. Comparison of above-ground biomass (2.79 to 43.77 MT ha^{-1}) with plantation of similar age indicates that present estimates of biomass are comparable with those of Poplar plantations studied elsewhere (Table 10). The large variability in above-ground tree biomass among different clones is probably related to factors such as genetic properties of individual clones, which were not measured in this study but are known to affect Poplar growth (Lehn and Higginbotham, 1982). Among different components, the proportion of biomass was maximum in stem followed by branches, bark and leaves. The proportion of biomass stored in roots were found to be 19.3-28.0 per cent of the total tree biomass, which are higher than

Table 11

Comparison of total net production with other plantations/forests of the world

Vegetation	Location	Age (yr)	Net production (MT $ha^{-1}yr^{-1}$)	Authors
Pine forest	India	-	9.9-21.2	Chaturvedi and Singh, 1987
Dry deciduous forest	India	-	14.6	Singh, 1979
Eucalypt forest	Australia	-	27.8	Rogers and Westman, 1981
Sal forest	India	-	16.0-18.9	Singh and Singh, 1989
Hybrid Poplar	USA	-	19.7	Bowersox and Ward, 1976
Poplar	Denmark	-	18.0	Bergstedt, 1981
Populus tremuloides	Canada	-	2.2-4.8	Bella and De Frenceschi, 1980
P. grandidentata	USA	-	2.9-11.0	Koerper and Richardson, 1980
P. deltoides	India	-	10.2	Kaul *et al.*, 1983
P. deltoides	India	4-10	5.9-22.7	Singh, 1989
P. deltoides	India	5-8	20.0-24.5	Lodhiyal *et al.*, 1995
P. deltoides	India	1-4	15.4-32.4	Lodhiyal and Lodhiyal, 1997
P. deltoides	India	4	1.09-21.88	Present study

the value 10-12 per cent reported for Eucalypt forest by Feller (1980) and equal to 5 year old Poplar plantations reported by Lodhiyal *et al.* (1992). Similar trend in different species of *Populus* had been observed by a number of researchers (Bella and Franceschi, 1980; Koerper and Richandon, 1980; Kaul *et al.*, 1983). The percentage contribution of the branches and leaves were much less as compared to stem component of the total biomass, which agrees with the values reported for 8 year old *Populus deltoides* plantation in U.P., India (Kaul *et al.*, 1983).

Net Primary Productivity (NPP) in the present study (4 year old plantation) ranged from 1.09 to 21.88 MT $ha^{-1}yr^{-1}$. NPP for the best growing clones was found to be higher to that reported (8.5 MT $ha^{-1}yr^{-1}$) in IC clones grown in Tarai region by Kaul *et al.* (1983). It is evident from Table 11 that comparison of net production with other plantations of the world, the values in the present study are within the range that reported by others. Whittaker and Woodwell (1971) estimated the NPP in many mature stable temperate forests of favourable environments is in the range 12-15 MT $ha^{-1}yr^{-1}$, which may be greater in young forests. In many tropical forests it may be up to, and in some cases, beyond 30 MT $ha^{-1}yr^{-1}$. In general, 10-20 MT $ha^{-1}yr^{-1}$ be taken as the normal range of NPP in a favourable climate. The fact that the productivity in the present study plantations with some clones (especially in the best five identified) are in the ranges of the values reported for temperate and tropical forests (Reichle, 1981), this indicates the favourable climate of Raipur for *P. deltoides* especially for 65/27, S7C1, G48, G3 and D121 clones.

Conclusion

For over two decades the suitability of *P. deltoides* clones has been established North India for commercial and agroforestry plantations. Outstanding success has been obtained above 28°N latitude and the need is felt to screen and evaluate clones suitable for other parts of India. The attempt in this direction at 21°N latitude has met with success. Among 106 clones tested 19 clones only were found to be performing satisfactorily under nursery conditions. Field plantations of these 19 clones has already completed half of its rotation since *Populus deltoides* is harvested at a short rotation of 6 to 10 years. Field trials indicate that clones with a high survival, overall growth, yield in terms of biomass and NPP, is the semi-evergreen 65/27 clone of Australian origin (derived from cross with Chilean semi-evergreen *P. deltoides*) followed by Stoneville S7C1 clone, Australian selection G48 and G3. Growth performance of the American clone D121 was poorest among the five best selected clones.

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SUMMARY

The study describes growth, biomass and net primary productivity in different clones of *Populus deltoides* Bartr. grown on vertisol type of soil at Raipur situated at 21°12'N latitude and 81°36°E longitude. Based on growth and survival performance of 106 clones in the nursery over successive two years, 19 clones were selected for field evaluation. Survival in the field in different clones ranged from 40 to 100 per cent. The best five clones in 4 yr old plantation was in order of 65/27 > S7C1 > G48 > G3 > D121. The above- ground biomass varied from 2.79 to 43.77 MT ha^{-1}, while that of coarse roots it was 0.67 to 10.5 Mg ha^{-1}. Stemwood in different clones varied from 33.7 to 62.2 per cent of the total biomass followed by coarse roots (16.5-28.0%), branches (7.4-23.7%), bark (7.5-12.9%) and leaves (5.3-10.3%). Net primary productivity also differed in different clones. The study concludes that some of the clones can be grown at 21°N latitude which was to date not considered a suitable region for the introduction of *P. deltoides*.

मध्य भारत के उपार्द्र उष्ण भागों में *पोपुलस डेल्टायडिस* बार्ट्र० की संभावनांए – अतिजीविता, बढ़वार और उत्पादकता

सुनील पुरी, एस०एल० स्वामी व ए०के० जायसवाल

साराशं

इस अध्ययन में 21°12′ उत्तर अक्षांश तथा 81° 36′ पूर्व देशान्तर पर स्थित रायपुर की वर्टिसोल प्रकार की मृदा में उग रहे *पोपुलस डेल्टायडिस* बार्ट्र० के विभिन्न कृन्तकों की बढ़वार, जैवपुंज और शुद्ध प्राथमिक उत्पादकता का वर्णन किया गया है । रोपणी में निरन्तर दो वर्षो से अधिक समय तक 106 कृन्तकों की बढ़वार और अतिजीविता सक्रियता के आधार पर क्षेत्र में मूल्यांकन करने के लिए उन्नीस कृन्तक चुने गए । इन विभिन्न कृन्तकों की क्षेत्र में अतिजीविता 40 से 100 प्रतिशत

तक रही । 4 वर्षीय पादपों में सर्वोत्तम पांच कृन्तक इस क्रम में रहे 65/27 > एस7सी1 > जी 48 > जी 3 > डी 121 । भूमि से ऊपर उनका जैवपुंज 2.79 से 43.77 मै०ट०/हेक्टे० तक रहा, जबकि स्थूल जड़ों का जैवपुंज 0.67 से 10.6 मै०ट०/हेक्टे० तक रहा । विभिन्न कृन्तकों में तनाकाष्ठ कुल जैवपुंज का 33.7 से 62.2% तक पाया गया जिसके उपरान्त क्रमशः स्थूल जड़ें (16.5 से 28.0%), शाखाएं (7.4 से 23.7%), छाल (7.5 से 12.9%) और पत्तियां (5.3 से 10.3%) रही । शुद्ध प्राथमिक उत्पादकता में भिन्न-भिन्न कृन्तकों में अन्तर पाया गया । इस अध्ययन का निष्कर्ष यह रहा कि इनमें से कुछ कृन्तकों को 21° उत्तर अक्षांश पर उगाया जा सकता है जो अभी तक *पो० डेल्टायडिस* को यहां लाकर लगाने के लिए उपयुक्त क्षेत्र नहीं समझा जाता था ।

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