SCOPE OF *POPULUS DELTOIDES* ON MARGINAL LANDS OF INDO-GANGETIC PLAINS

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Introduction

Populus is one of the fastest growing genera throughout the world. Out of the six indigenous and eight exotic species, *Populus deltoides* (Cotton wood) has acquired the most promising status in Northern India particularly in agroforestry land use systems (Mathur and Sharma, 1983; Chaturvedi, 1982, 1983; Chandra, 1986; Tandon *et al.,* 1991). It has been widely accepted in Tarai region of Uttar Pradesh on account of having suitable canopy characteristics and shallow root system for intercropping (Singh, 1998a; Singh, 1994). The deciduous nature of *P. deltoides* does not cast any shade effect on Rabi season's crop as the trees become completely leafless during winter. Perhaps this character associated with a relatively fast growth has almost replaced the farming of evergreen *Eucalyptus* with Poplars in Indo-Gangetic plains of U.P. Besides, nutrient recycling by the decomposition and mineralization of leaf litter is relatively fast in Poplar (Singh *et al.,* 1993) which also adds another merit over *Eucalyptus* in farm forestry. *Populus deltoides* grows well to its intrinsic potential on deep fertile sandy loam to clay loam alluvium with high water holding capacity at the rate of 2-3 m per year during initial 4 years (Shelton *et al.*, 1982; Singh and Mittal, 1983). Performance levels of several newly introduced clones at Forest Research Institute, Dehra Dun were reported recently and their future strategy has been planned (Kumar *et al.*, 1999; Singh *et al.*, 1999). The scope of Poplar on a large tract of marginal lands, widely spread over the Gangetic plains, has been explored. Since these marginal lands have become impoverished and cannot nourish adequately the fast growing species, some sort of biotechnological interventions are required to ameliorate the soils atleast partially *prior to undertake Poplar plantations.*

A clone evaluation trial with several *P. deltoides* clones raised on marginal lands identified the best selection (Singh and Misra, 1995). Later on, their silviculture technology was also standardized (Misra and Tiwari, 1999). Productivity dynamics and nutrient cycling in some clones of *P. deltoides* has been studied (Singh, 1998a,b). Singh and Behl (1999) have recently worked on the sustainability of Poplar plantations on degraded lands by investigating the resource use efficiencies. In this paper 3 suitable clones were evaluated for biomass production and nutrient accumulation in 2 sets of plantations raised with different objectives. The one was a high density short rotation (4 yrs.) energy plantation (HDSREP) and the another was a conventional agroforestry plantation (AFP) of 10 years rotation. Generally Poplar plantations on marginal lands are raised either for mitigating the demand of biomass energy or industrial pulp in fuelwood or fibre production, respectively for which a high quality land would not be available at the cost of any risk in country's food security.

Material and Methods

Two sets of *Populus deltoides* plantations were raised on Banthra Research Station of NBRI, Lucknow during 1985 to 1995 (26, 45'N, 80°53'E). The first set was a CRD trial of high density short rotation (4 yrs.) energy plantation (HDSREP) at the spacing of 60 x 40 cm with a population density of about 40,000 plants per hectare. The plot size was 10 x 10 m, with four replications of each of the three clones (G3, G48 and D121). The second set was a CRD trial of agroforestry plantation (AFP) for a rotation of 10 years at the spacing of 3m x 3m with a population density of about 1,100 plants per hectare. In this trial, plot size was relatively large of 33 m x 33m with four replications of each of the three clones (G3, G48 and D121). The plantations were growing in a seasonally monsoonic climatic with an average annual rainfall of 970 mm. Average maximum and minimum temperature was recorded as 32.1 and 18.6°C. Average relative humidity was 63%. Total incident solar radiation has been recorded as 69T J/ha/yr. Data reported in this paper at the age of 2 and 4 years belong to HDSREP trial and rest at age 6, 8 and 10 years are related to AFP trial.

Both the plantations were developed on a marginal land of Gangetic alluvium which was partially reclaimed through the other primary land use systems to a level of pH 8.5 to 9; EC 0.2 to 0.4 dSm^{-1}, organic carbon 0.1% to 0.3%, N 0.2 to 0.5 mg g^{-1}. The soil was still not ideal for Poplar plantations owing to incomplete amelioration in chemical, nutritional, structural, hydrological and microbiological characteristics. However, these limitations in general remain associated with every species, when planted under the present set of degraded conditions. Therefore, in order to develop an economically feasible and ecologically viable land use system *Populus deltoides* was introduced to use the marginal lands more efficiently over the traditional agriculture and/or fuelwood forestry programmes.

Periodical growth measurements and biomass assessment were carried out through the harvesting of sufficient sample plants (> 100 in trial I and 60 in trial II) from entire size variations and developing the allometric regression equation of the form :

$\ln y = a + b \ln x$

where

y = biomass and

x = DBH.

DBH was chosen for practical reasons as it is more time consuming to measure stem height. Furthermore the inclusion of height in the independent variable mostly as D^2H, in general does not contribute significantly to biomass yield estimates (Crow 1971; Singh and Misra, 1995; Verwijst and Telenius, 1999).

Energy values were determined through the Par Oxygen Bomb Calorimeter, Mellinoise (USA). Carbon was estimated by igniting the 3 replicate samples (1g each) in muffle furnace at 600°C for four hours and loss on ignition (organic matter) was corrected with standard per cent of O_2 (42%) and hydrogen (6%) with actual N concentrations in the sample. N was analysed by microkjeldahl digestion and distillation unit. Phosphorus was determined by spectrophotometer blue colour method (Jackson, 1958). Ca, K, and Na elements were measured by flame photometer and Mg was determined by atomic absorption spectrophotometer. The samples used in the analysis were composite i.e. collected from different size plants of each clone.

Results and Discussion

In high density short rotation (4 yrs.) plantation, clone D121 was found better than other 2 clones, whereas, in agroforestry plantation (10 yrs.) clone G3 and G48, both performed equally well; D121 was rather unsuccessful (Table 1). If we compare a 4 year high density energy plantation with an 8 year low density agroforestry plantation, clones G3 (38.7 and 37.2 t/ha) and G48 (32.2 and 36.2 t/ha) produced almost compatible biomass. Thus by manipulating the population density, one can ensure a modest yield event at a very young age particularly when the wood is required to be used for energy purposes as fuelwood or in gasfires. A species capable of producing about 10 t/ha/yr biomass is generally found acceptable in biomass

Table 1

Biomass production of three Populus deltoides clones in even-aged plantation raised on marginal land at Banthra, Lucknow

Age (yrs.)	Clone	Population density (Nos/ha)	Basal area (m^2/ha)	Aboveground biomass (t/ha)	Belowground biomass (t/ha)	Total biomass (t/ha)	Root/Shoot Ratio
2	G3	25830	12.44	20.13	3.91	24.04	0.19
	G48	11530	11.84	20.35	3.38	23.73	0.17
	G121	19530	15.13	25.16	4.53	29.69	0.18
4	G3	17320	14.31	32.52	6.21	38.73	0.19
	G48	8540	13.22	28.40	5.76	34.16	0.20
	G121	9210	16.62	33.20	6.82	40.02	0.20
6	G3	923	8.25	24.43	4.75	29.18	0.19
	G48	942	6.86	19.40	4.02	23.42	0.21
	G121	843	3.03	7.09	1.41	8.50	0.20
8	G3	860	10.12	30.50	6.69	37.19	0.22
	G48	864	9.41	29.81	6.38	36.19	0.21
	G121	753	3.76	9.68	1.93	11.61	0.20
10	F3	798	11.9	40.06	8.63	48.69	0.21
	G48	785	11.8	40.22	8.75	48.97	0.22
	G121	664	4.6	12.28	2.46	14.74	0.20

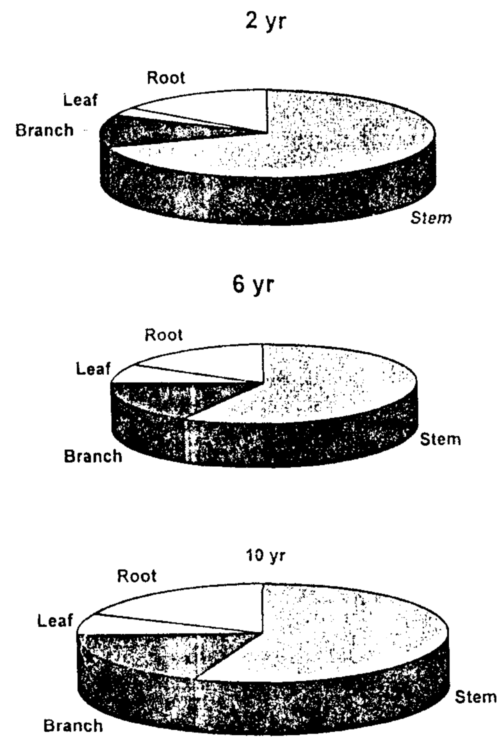
energy plantation programmes, in which *clone D121 qualified well on these marginal* lands. However, the potential of Poplar (clones G3 and G48) in farm forestry was not as good as found in Tarai regions of U.P. (Tandon *et al.*, 1991; Lodhiyal *et al.*, 1995).

Root/shoot ratio slightly increased with age and spacing from 0.18 to 0.21 (Table 1). Singh (1994) noticed that root/shoot ratio increased from 0.22 to 0.33 when spacing was increased from 2 m x 2 m to 4 m x 4 m. In fertile plains root/shoot ratio was relatively less with an increase from 0.10 to 0.13 with respect to age and spacing (Tandon *et al.*, 1991). In Himalayan foot hills root/shoot ratio increased from 0.24 to 0.27 between 3 and 8 years (Lodhiyal *et al.*, 1995). Thus our root/shoot ratio lies in the middle of the range (0.10 to 0.33) reported earlier (Tandon *et al.*, 1991; Singh, 1994). The root/shoot ratio is important for allocation of organic matter into the usable components (above-ground) with a standard specification *of 0.75 : 0.25, for shoot and* roots, respectively.

As regards the proportion of biomass in each component, stem constituted the greatest proportion of about 70% in young plantation at 2 years which considerably decreased in old plantation of 10 years (56%) due to wide spacing with relatively less competition among the individuals (Fig. 1). The root proportion, however, increased slightly from 15 to 18%. Concentrations of energy, carbon and other nutrients showed that these clones did not differ much in energy and carbon values, but N of course was relatively less in G48 clone (Table 2). C was greater in wood than leaf against the inverse pattern for other nutrient between these two components. Similar was the case with Na concentrations also. In general, nutrient concentration in Poplar was higher than many other *industrially important timber species* (Srivastava *et al.,* 1988). With these qualitative measures, quantitative measures of energy and nutrient contents for different clones were obtained. As with biomass, 4-yr HDSREP consisted of nearly similar energy content to that of 8 year old AFP for clone G3 and G48. Whereas, clone D121 did not succeed in AFP plantation although it remained competitive in HDSREP with the other two clones (Fig. 2).

Nutrient storage in total biomass (above + belowground) of even-aged

Fig. 1



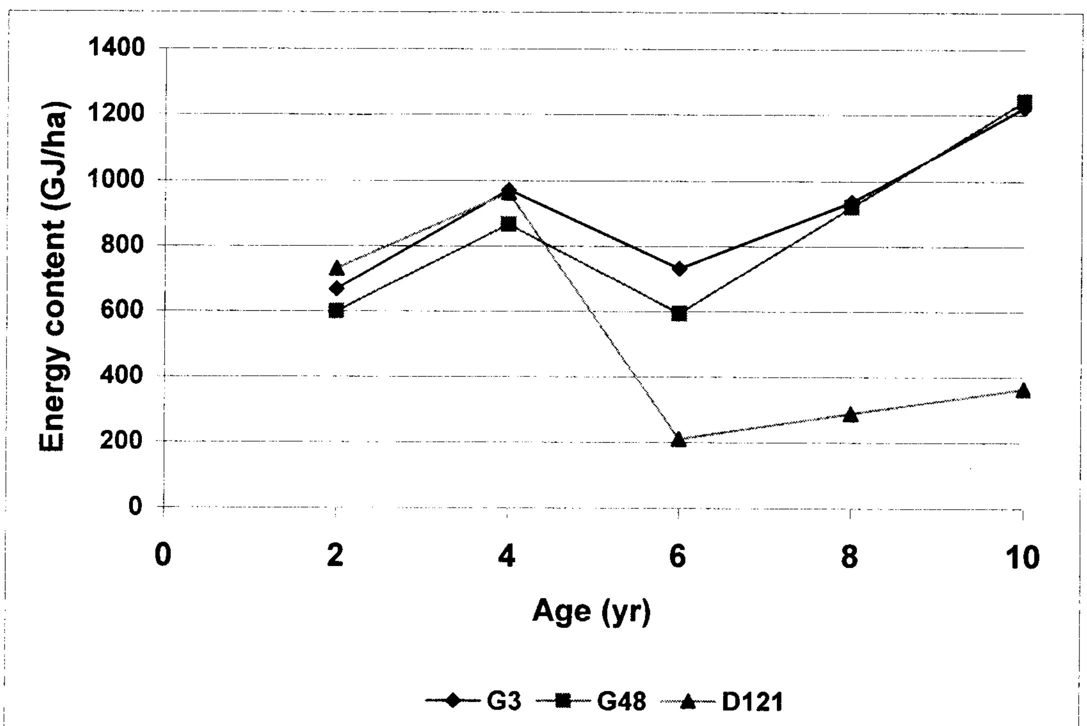
Biomass proportions in different components over the years
(Average of 3 clones. % of total)

Table 2

Energy value and nutrient concentrations in leaf and woody components in three Populus deltoides clones

Parameter	G3		G48		D121	
	Leaf	Wood	Leaf	Wood	Leaf	Wood
Energy (kJ/g)	25.40	25.06	26.90	25.30	23.70	24.90
C (%)	40.00	47.20	39.40	47.90	38.80	46.30
N (%)	2.27	0.76	1.62	0.40	1.93	0.70
P (%)	0.24	0.18	0.21	0.19	0.20	0.20
K (%)	1.26	0.41	1.23	0.46	0.93	0.31
Ca (%)	1.57	0.57	1.55	0.64	1.33	0.28
Mg (%)	1.40	0.22	0.98	0.35	0.85	0.38
Na (%)	0.40	0.36	0.28	0.31	0.41	0.37

Fig. 2



Energy content in three *Populus deltoides* clones over the years (GJ/ha) plantations are the functions of nutrient concentrations in different components and their biomass (Table 3). It is important at harvestable age (4 yr and 10 yr) to assess the losses from biomass removals particularly for the most growth liming nutrient - N. It appears that clone G48 is superior to have least accumulation of N at a compatible biomass with other clones. If we analyse the biomass nutrient ratio, clone G48 stands better than others both in HDSREP and AFP. Singh (1998b) has observed a tight N cycle in plantations of clone G3 and loose cycle in clone G48 to accomplish the greater N demand of former through a high retranslocation. A loose cycle increases the N use efficiency for better biomass production as in case of G48. Thus, clone G3 dominated in N removal from the site during wood extraction invariably either at 4 yr or 8 yr in different sets of plantations.

It is no doubt, that biomass potential of *P. deltoides* on marginal land in quite low to that of better sites reviewed in Table 4. Even then, its scope in managing the unproductive marginal lands under suitable land use systems can not be ruled out. Either in HDSREP or in AFP, Poplar adds to some additional benefits shortly where other slow growing trees do not generate the equivalent wood in such a short time

Table 3

Nutrient accumulation in 3 clones of Populus deltoides raised on marginal lands

Age (yr.)	Clone	C	N	P	K	Ca	Mg	Na
2	G3	11.34	190.25	43.57	102.81	142.03	58.78	86.74
	G48	11.32	102.24	45.21	113.77	157.30	86.83	73.38
	D121	13.69	216.41	59.38	96.38	90.48	237.87	110.13
4	G3	18.26	312.44	70.43	168.65	232.76	99.36	139.90
	G48	16.25	153.74	65.18	167.91	231.47	128.38	105.48
	D121	18.42	297.32	80.04	132.74	127.36	158.66	148.63
6	G3	13.74	252.00	53.72	136.60	186.33	87.79	105.84
	G48	11.06	115.68	44.86	121.59	166.26	90.31	22.06
	D121	3.86	71.80	17.00	32.55	34.30	37.00	31.85
8	G3	17.54	327.90	68.74	177.98	241.88	117.22	135.10
	G48	17.11	175.30	61.26	185.72	254.38	142.42	111.40
	D121	5.30	93.57	23.22	42.19	43.00	48.80	43.36
10	G3	22.97	430.40	92.22	233.63	317.53	132.20	176.88
	G48	23.32	232.20	93.51	248.36	340.71	190.29	150.91
	D121	6.68	127.78	29.48	58.09	62.27	65.41	55.34

Table 4

Biomass potential of Populus deltoides at various sties

Age (Yr.)	Clone	Density /ha	Location	Above ground biomass (t/ha)	Below ground biomass (t/ha)	Total Biomass (t/ha)	Root/ Shoot	Reference
2	G3	25830	Lucknow	20.1	3.9	24.0	0.19	Singh and Misra (1995)
2	G48	11530	Lucknow	20.3	3.4	23.7	0.17	Singh and Misra (1995)
2	D121	19530	Lucknow	25.2	4.5	29.7	0.18	Singh and Misra (1995)
4	D121	9210	Lucknow	33.2	6.81	40.01	0.20	Present study
5	G3	400	Dehra Dun	52.4	10.7	63.1	0.20	Tandon *et al.* (1991)
5	D121	400	Nainital	67.4	16.2	83.6	0.24	Lodhiyal *et al.* (1995)
6	G3	923	Lucknow	24.6	4.6	29.2	0.19	Singh (1998a)
7	-	500	Pantnagar	111.8	14.3	126.1	0.13	Mohsin *et al.* (1999)
8	1C	500	Dehra Dun	160.0	20.0	126.00	0.16	Kaul and Sharma (1983)
8	1C	500	Dehra Dun	71.7	14.3	86.0	0.17	Kaul *et al.* (1983)
8	D121	400	Nainital	134.3	35.7	170.0	0.27	Lodhiyal *et al.* (1995)
8	D121	400	Alabama	89.7	-	-	-	Carter and White (1971)
9	G3	625	Hisar	88.0	29.3	117.3	0.33	Singh (1994)
9	G3	400	Dehra Dun	76.0	12.8	88.8	0.17	Tandon *et al.* (1991)
9	D121	500	Lucknow	34.6	5.2	39.8	0.15	Misra and Tiwari (1999)
10	G8	785	Lucknow	40.3	8.6	48.9	0.21	Singh (1998b)
10	D121	400	Nainital	105.4	-	-	-	Singh (1989)
14	G3	400	Dehra Dun	44.5	-	-	-	Raizada and Srivastava (1984)
16	D121	125	USA	133.7	-	-	-	Shelton *et al.* (1982)

even *Eucalyptus* also (Chaturvedi and Behl, 1995). Besides, Poplar wood has manifold applications and wide market, against the slow growing species for only limited applications as firewood. *P. deltoides* grows faster during initial 3 to 4 years after that growth is declined gradually. On our site, MAI of about 10 t/ha in HDSREP and 5 t/ha in AFP was a modest potential to keep the options open for Poplar cultivation on marginal land unless some other more economically feasible opportunities come out. The spacing and population density are decided according to the specific purpose of plantation either for biomass energy (Short rotation) or for fibre production (AFP). A very long rotation for saw logs would not be possible on marginal land. Numerous experiments carried out on marginal lands at Banthra Research Station of NBRI reveal a modest potential of cropping of *P. deltoides* with following specifications :

1. Suitable clones, G3, G48, D121, ST-148, ST-163 S7C15 (further screening of new clones are underway).
2. HDSREP - spacing 60 x 40 cm for 4 yr rotation, clone D121.
3. AFP - spacing 5 x 4 m (N-S wide) for cereal crops.
4. AFP-Silvipastoral system 3 x 3 m with fodder legumes viz. *Alysicarpus monilifer, Indigofera linifolia, Desmodium triflorum* and clone G3 and G48.
5. Judicious use of chemical fertilizers along with application of biofertilizers.
6. Maintenance of proper drainage with light and frequent irrigation during summer.
7. *P. deltoides* is recommended in secondary plantations i.e. primary land use system should be purely indigenous with the biotechnological interventions to reclaim the soil substantially particularly if soils are of sodic nature.
8. Pretreatment of plantation pits with suitable amenders as per soil condition.

SUMMARY

Experimental plantations of 3 clones of *Populus deltoides* (G3, G48 and D121) were evaluated in high density short rotation (4 yrs.) energy plantation (HDSREP) and conventional agroforestry plantations (AFP) of 10-yrs rotation on marginal lands. Clone D121, which was found better in HDSREP did not perform well in AFP trial. Whereas, clone G3 and G48, produced almost compatible biomass at 4 yrs and 8 yrs in these 2 sets of plantations. Proportions of stem biomass decreased with age. Nutrient accumulation was relatively high in G3 and D121 clones. Clone G48 has accumulated lowest N content in biomass and therefore appears to be better in nitrogen use efficiency. There are ample scope of Poplar cultivation on marginal lands of Gangetic plains to ensure some additional benefits either in HDSREP or in AFP over the slow growing indigenous trees. However, it is recommended in secondary plantation programmes to support and sustain the fast growth of this species. At first instance, abandoned marginal lands must be ameliorated substantially through the primary land use systems preferably with indigenous leguminous species. Therefore, cultivation of Poplar may be carried out to utilize such lands more efficiently with the appropriate soil and water management practices. However, yields equivalent to Tarai region of U.P. can not be expected due to limitations of environmental conditions.

सिन्धु–गांगेय मैदान की सीमान्त भूमियों में *पोपुलस डेल्टायडिस* लगाने की सम्भावाएं

बजरंग सिंह व एव०एम० बेहल

सारांश

पोपुलस डेल्टायडिस के 3 कृन्तकों (जी3, जी48 और डी 121) को सीमान्त भूमियों पर उच्च सघनता छोटा आवर्तन

(4 वर्ष) ऊर्जा रोपवन और 10 वर्षीय पारम्परिक कृषिवानिकी रोपवन विधि से संपरीक्षात्मक रोपवन लगाकर मूल्यांकित किया गया । कृन्तक डी 121, जो उच्च सघनता छोटा आवर्तन वाले संपरीक्षात्मक रोपवन में श्रेष्ठतर रहता पाया गया कृषिवानिकी रोपवनों में अच्छा नहीं चला । जी3 और जी48 कृन्तकों से इन दोनों प्रकार के रोपवनों में 4 वर्ष और 8 वर्ष की उम्र हो जाने पर लगभग तुलनीय जैवपुंज उत्पन्न हुआ किन्तु उम्र बढ़ती जाने के साथ तने के जैवपुंजों का समानुपात घटता गया । पोष्याहार संचयन जी 3 और डी 121 कृन्तकों में अपेक्षतया अधिक होता पाया गया और इसलिए नाइट्रोजन उपयोग करने की क्षमता की दृष्टि से ये अधिक अच्छे प्रतीत होते हैं । मन्दवर्धी देशज वृक्षों को लगाने की तुलना में गांगेय मैदानों की सीमान्त भूमियों पर उच्च सघनता छोटा आवर्तन वाले संपरीक्षात्मक रोपवन अथवा कृषिवानिकी रोपवन लगाने पर होने वाले अतिरिक्त लाभ मिलना सुनिश्चित बनाने के लिए पोपलर लगाने की बहुत संभावनाएं हैं । तथापि, हमारी सिफारिश है कि इस जाति के शीघ्रवर्धन को सहायता पहुंचाने और उसे बनाए रखने के लिए इसे द्वितीयक रोपवनों में ही लगाया जाना चाहिए । लगाने से पूर्व परित्यक्त सीमान्त भूमियों का, उन पर प्राथमिक भूमि उपयोग प्रणालियों द्वारा, अच्छा रहेगा, शिम्बिवर्गीय देशज जातियां लगाकर, भलीभांति सुधार कर लिया जाना चाहिए । इसके बाद, उपयुक्त मृदा और जल प्रणालियां अपनाकर उन भूमियों पर पोपलर की खेती कराकर अधिक कार्यदक्षतापूर्वक उन भूमियों को उपयोग में लाया जाना चाहिए । किन्तु, पर्यावरण दशाओं की बाध्यताओं को देखते हुए इनसे उत्तर प्रदेश के तराई क्षेत्र के बराबर की प्राप्ति पाने की प्रत्याशा नहीं की जा सकती ।

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