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Genetic Variability Assessment of Growth Traits and Nutrient Uptake of *Populus deltoides* under Punjab Conditions

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Abstract: The present study was conducted on 7-year-old *Populus deltoides* clones for growth, biomass and nutrient uptake characteristics under Punjab conditions at Punjab Agricultural University, Ludhiana which falls under the Central Plain Zone. Observations on total height, diameter at breast height, volume and biomass were recorded, and nutrient uptake was worked out. Significant differences were observed among clones for all the characteristics. The clone FNR-558 was observed as most promising clone for DBH, volume and biomass. The highest value for nitrogen uptake was observed in L-47/88. For phosphorus and potassium uptake was maximum in clone FNR-558. Majority of parameters studied except straightness were less influenced by the environment conditions and thus reflect the variability for the traits in *Populus deltoides* is tightly linked with the genotypic constitution. High heritability (69.80%) coupled with moderate genetic gain (16.57) was observed for volume. Genotypic correlation coefficient higher than phenotypic correlation coefficient revealed the less effect of the environment on the expression of these traits and would be helpful in future breeding programs. FNR-558 recorded highest index score followed by Ranikhet, FNR-544, L-170/88 and L-247/84, therefore showing promising results.

Keywords: *Populus deltoides*, Clones, Growth, Nutrient uptake, Genetic parameters, Correlation, Path analysis, Index score

In India, the term 'poplar' is used synonymously with *Populus deltoides*, an exotic species introduced from North America during the early 1950s and has gained much popularity as commercial timber tree, due to multifarious uses, market potential and fast rate of growth. *P. deltoides* is the main exotic Poplar in India and widely cultivated in the Indo-Gangetic plains of north-western region of India (Kumar and Singh 2012). Poplar grows excellent in soil having >10 % soil porosity, 35% or much less clay content material and pH range in between 6.5-8.0 (Dhillon and Sidhu 2007). In India, the farmers of north-western states adopted the poplar tree for its higher productivity (up to 48 m^3 $ha^{-1}year^{-1}$), short rotation (5-7 years), straight stem and compatibility in agroforestry systems (Dhillon et al 2010a).

Poplar is the major species behind the development of a vibrant plywood industry in north-west India. It is also used to a significant extent in match industry. The waste wood is used for making paper or as fuel. Every year poplar in non-forest area produces 1.20 million m^3 wood for making plywood and is thus saving 43,000 ha natural forests or 13,500 ha forest plantations from felling every year to produce the same quantity of wood. Farmers are earning handsome profits from nursery as well as plantation activities (Tomar and Srivastav 2020). Farmers in Punjab, Haryana, and Uttar Pradesh began growing poplar trees commercially as a means of diversifying their rice-wheat crop rotation which can provide high economic returns compared to the traditional cropping system (Singh et al 2022). The species is propagated by vegetative methods, resulting in intra and inter-specific hybridization.

Commercial poplar plantations in India mainly rely on a few clones, including G-3, G-48 and WSL series, resulting in a narrow genetic base that makes the plantations susceptible to insects and leaf spot diseases (Singh et al 2004). Such limited hereditary base of clonal plantations may pose a huge risk to the long-term productivity and recommendation is to replace 5 to 10% of available clones annually. Accordingly systematic breeding and selection work was started at Punjab Agricultural University since past three decades and many clones were put for field evaluation for commercial cultivation. Different promising clones have been developed by various research organizations in the nation and are being tested in a number of locations to meet the ever-increasing demand for poplar wood as well as farmers' interest in poplar cultivation. Due to limited number of clones present for cultivation under Punjab conditions there might be a chance the few of these clones may become susceptible to various diseases or insect pests which will affect large number of plantations in the region (Dhillon et al 2020). To have diverse number of clones for cultivation and to select high performing clones it is important to evaluate various new clones under these conditions. There is a lack of data on biomass production and nutrient uptake in these poplar clones. This paper reports the clonal variability in growth traits, biomass production in poplar at age of 7 years.

MATERIAL AND METHODS

The research study evaluated twelve clones of *Populus deltoides* under field conditions at Punjab Agricultural University, located central part in Ludhiana (30° 54´ N latitude, 75° 48´ E longitude, and at an altitude of 247 m amsl. The climate in Ludhiana is characterized by hot summers and desiccating winds from April to June, and cold winters with occasional ground frost from December to January. Most of the 760 mm annual average rainfall in the area occurs between July and September. The study was conducted on 7-year-old trees that were established under a randomized block design with three replications and a plot size of 5 trees. The growth parameters like tree height, diameter at breast height, crown length, number of branches per meter of crown length; stem quality traits like clear bole height and straightness; and yield traits like volume and biomass; and nutrients accumulation by trees were recorded. For estimation of volume, trees were converted into commercial logs. The volume of single tree was then calculated by summation of volume of all logs. Biomass of trees was calculated at the time of harvesting by weighing individual logs and branches on a weighing machine and adding them together (kg tree^{-1}).

Nutrient uptake in polar clones was determined by evaluating the nutrient content from different plant parts. For this plant samples were taken from different parts of tree like tree bole, branches and leaves. For determination of N, plant samples were digested with H_2SO_4 and for P and K, these samples were digested with nitric acid and perchloric acid in the ratio of 3:1. Nitrogen Determination was done via Kjeldahl method. Vanadomolybdo phosphoric yellow colour method in a nitric acid system was used to quantify the total phosphorus in plant extracts and potassium using flame photometer's atomizer assembly. Final values of the nutrients which were in percentage were then multiplied with biomass to calculate nutrient uptake per tree. For nutrient uptake per acre by the poplar planted at 5m x 4m spacing (500 trees/ha) the nutrient uptake was calculated as: Nutrient uptake per acre (kg) = Nutrient uptake per tree (kg) × 500 trees per ha.. Statistical analysis was done using CPCS1 software developed by PAU Ludhiana and aassociation studies (Al-Jibouri et al 1958), path analysis (Wright 1921, Dewey and Lu 1959).

RESULTS AND DISCUSSION

There were significant differences among the tested clones for all the growth and yield characteristics (Table 2). Clone FNR-558 had the highest DBH (21.42 cm), which is statistically at par with almost all clones except L-17/92, L-290/84 and L-168/88 had the lowest value (18.80 cm). Seven clones had higher DBH than the overall mean, with FNR-558, Ranikhet, and L-47/88 being the top three. The maximum tree height (17.75 m) was in L-170/88, which was statistically superior to four clones i.e. L-290/84, L-17/92, WSL-29, and L-168/88. The tree volume ranged from 0.180 m^3 to 0.243 m^3 per tree. Four clones recorded higher value for volume than overall mean in order of FNR- 558 > Ranikhet > L-47/88 > FNR-544. The clone FNR-558 and Ranikhet had the highest mean biomass, while L-168/88 had the lowest (Fig. 1). All clones were statistically at par with FNR-558 except L-290/84, L-17/92, L-47/88, and L-168/88 clones. Six clones had a higher biomass than the overall mean, FNR-558followed by Ranikhet, L-47/88, FNR-544, L-170/88, and L-247/84, in that order. This indicates the existence of adequate genetic variability in the experimental material which could be exploited for further recommendation of these clones for commercial cultivation. Understanding the factors that contribute to these variations can aid in selecting suitable clones for specific purposes. Singh et al (2008) assessed the growth traits in 20 *P. deltoides* clones in Punjab and recorded significantly variations.Sidhu and Dhillon (2007), Dhillon et al (2010b, 2013), Otis-Prud'homme et al (2023) and Zhao et al (2013) collectively also indicate significant variations in the growth performance of poplar clones at different ages.

The mean value of clear bole height ranged from 9.50-10.88 m (Table 2). The maximum clear bole height was in cloneFNR-558 followed by L-247/84, whereas minimum clear bole height was in clone FNR-544 (9.50 m). Mean value of crown length and number of branches per meter crown length ranged from 5.25 m (L-168/88) to 8.22 m (FNR-558), and from 4.15 (Ranikhet) to 5.97 (L-48/89). The highest mean value for straightness was in L-247/84 (3.80) followed

Table 1. Description of poplar clones used in the research experiment

Source	Clone
Local selection	FNR-558, FNR-544
Dr Y S P University of Horticulture & Forestry, Nauni	Ranikhet
Uttarakhand State Forest Department, Lalkuan	L-170/88, L-247/84 , L-290/84 ,L-168/88 .L-17/92 ,L-47/88 (Check), L-48/89 (Check)
Wimco Seedling Pvt. Ltd.	WSL-29
Dr Y S P University of Horticulture & Forestry, Nauni	RD-01

by L-48/89 (Check) while the minimum value for straightness was in L-168/88. There were significant variations among all the stem quality parameters among poplar clones except in straightness score. These are the traits are those which are affected by both genetic make-up as well as environmental conditions in which the trees are growing. The clone FNR-558 showed outstanding performance for stem quality traits. Dhillon et al (2013) also observed substantial variations in number of branches, and crown width across 36 poplar clones. Jha (2020) evaluated forty genotypes of poplar for juvenile wood yield and its components, and revealed significant differences.

Significantly differences for nitrogen uptake were observed among the clones which varied from 603.28 kg/ha (L-168/88) to 1471.68 kg/ha (L-47/88). Clone FNR-558 showed the highest mean value for phosphorous (177.68 kg/ha) and potassium (956.7 kg/ha) uptake, while L-17/92 exhibited the lowest (95.4 kg/ha and 613.38 kg/ha, respectively). Nitrogen uptake efficiency varied among the clones, with four clones L-290/84, FNR-544, L-168/88 and L-48/89 demonstrating higher values, and lowest value was in L-47/88 (Fig. 2). Clone L-17/92 registered higher biomass per kg uptake of the phosphorus and potassium. Among different nutrients, uptake of nitrogen was highest among all the poplar clones and was followed by uptake of potassium while phosphorus uptake was the lowest among all three nutrients.

In general, the phenotypic coefficient of variation was higher than the corresponding genotypic coefficient of variation for all traits reflecting the sufficient genetic variations for the traits studied among clones (Table 4). Low genotypic variance was observed in general. A high heritability indicated that much of the variation for a given characteristic observed in the clones is genetic in origin. Very high heritability (>60%) was in crown length, tree height, DBH and CBH, which means that the traits were under the strong influence of additive gene action and selection would be quite effective, whereas lowest heritability was recorded for straightness (28.29%). In the current study, the trend of genetic advance as per cent of mean shows a huge scope for genetic improvement in *P. deltoides.* The moderate genetic gain (17.68%) was recorded for crown length followed by volume (16.57%). This indicates that selection should be based on volume. Similar finding were also reported in Poplar by Dhillon et al (2010b) and Liu et al (2023), Kumar and

Table 3. Variation in nutrient uptake by the clones of *Populus deltoides*

Clone	Nitrogen (kg/ha)	Phosphorous (kg/ha)	Potassium (kg/ha)
FNR-558	1307.95	177.68	956.70
Ranikhet	1362.03	138.43	936.48
L-170/88	992.18	129.18	797.23
L-247/84	1096.20	125.13	791.35
L-290/84	631.03	118.25	697.10
WSL-29	1034.40	142.78	751.95
FNR-544	743.93	122.88	838.58
RD-01	988.45	130.68	765.75
L-168/88	603.28	107.23	626.00
L-17/92	1053.13	95.40	613.38
L-47/88 (Check)	1471.68	119.70	888.85
L-48/89 (Check)	742.50	117.43	682.68
CD (p=0.05)	27.01	1.61	10.74

Table 2. Variation in growth and stem quality traits among 12 clones of *Populus deltoides* under field conditions (Age 7 year)

Clone	Tree height (m)	Diameter at breast height (cm)	Crown length (m)	Number of branches per meter crown length	Clear bole height (m)	Volume (m^3 $tree^{-1}$)
FNR-558	17.44	21.42	6.57	5.86	10.88	0.243
Ranikhet	17.27	21.39	7.14	4.15	10.12	0.240
L-170/88	17.75	20.47	7.23	5.56	10.53	0.210
L-247/84	17.61	20.26	6.90	5.71	10.71	0.207
L-290/84	16.75	19.14	6.68	5.94	10.07	0.180
WSL-29	16.53	20.24	6.25	5.85	10.28	0.207
FNR-544	17.72	20.49	8.22	5.92	9.50	0.213
RD-01	16.94	20.17	7.05	4.98	9.89	0.207
L-168/88	14.92	18.80	5.25	5.45	9.67	0.170
L-17/92	16.47	19.64	6.77	5.18	9.71	0.190
L-47/88 (Check)	17.03	20.63	6.69	4.46	10.33	0.220
L-48/89 (Check)	17.08	20.01	6.54	5.97	10.54	0.203
CD (p=0.05)	0.96	1.44	1.13	1.03	0.61	0.040

Dhillon (2016) and Meena et al (2014) indicated that selection *Eucalyptus*and *Melia*should be based on volume rather than tree height, clear bole height and straightness as they have low genetic gain.

The genotypic correlation coefficient values were higher than corresponding phenotypic values for almost all the traits indicating the less effect of environment and true representation of genotype by phenotype (Table 5, 6). Majority of growth traits had significant and positive correlation. Volume showed very strong positive association with the DBH (g=1.003, p=0.984), whereas, negative and moderate association with the number of branches per meter crown length and a weak non-significant association with straightness. The DBH (1.395) had the most direct and positive effect on volume followed by tree height (1.091) at genotypic level, while, 0.964 at phenotypic level (Table 7, 8). In similar studies Jha (2012) and Parthiban et al (2017), reported high positive direct effect of DBH on volume and negative direct effect of tree height on volume.

AUTHORS CONTRIBUTION

Divyanshu Sharma involved in planning, data collection and analysis. GPS Dhillon planned the study, planted the trial and analysed the data. Ashok Kumar Dhakad involved in analysis of data. Baljit Singh helped in collection of soil samples and laboratory analysis of wood and leaf samples.

Table 4. Genetic parameters of variation in poplar clones

Parameter	GCV (%)	PCV (%)	Heritability (%)	GA	GAM (%)
Volume (m^3tree^{-1})	9.63	11.53	69.80	0.03	16.57
DBH (cm)	3.62	4.29	71.41	1.28	6.30
Tree height (m)	4.36	4.97	76.93	1.34	7.88
Clear bole (m)	4.03	4.76	71.78	0.72	7.03
Crown length (m)	9.73	11.04	77.76	1.20	17.68
Branches per meter crown length	9.70	13.85	48.99	0.76	13.98

Table 5. Genotypic correlation coefficient among different characters of *Populus deltoides*

Genotypic correlations	Volume (m^3 $tree^{-1}$)	DBH (cm)	TH (m)	CBH (m)	CL (m)
DBH (cm)	1.003				
Tree height (m)	0.723	0.782			
Clear bole (m)	0.546	0.548	0.494		
Crown length (m)	0.496	0.549	0.869	-0.080	
Branches per meter crown length	-0.406	-0.398	0.087	0.241	-0.060

DBH: Diameter at breast height, TH: Tree height, CBH: Clear bole height, CL: Crown length

Table 6. Phenotypic correlation coefficient among different characters of *Populus deltoides*

Genotypic correlations	Volume (m^3 $tree^{-1}$)	DBH (cm)	TH (m)	CBH (m)	CL (m)
DBH (cm)	0.984**				
Tree height (m)	0.627**	0.624**			
Clear bole (m)	0.419*	0.397*	0.428**		
Crown length (m)	0.401*	0.430**	0.769**	-0.143	
Branches per meter crown length	-0.255	-0.252	0.00	0.094	-0.035

Abbreviation See Table 5 for details

Table 7. Direct and indirect effect of all the independent components on volume using genotypic correlations

Path using genotypic correlations	DBH (cm)	TH (m)	CBH (m)	CL (m)	NOB	Genotypic correlation with volume
DBH (cm)	1.395	-0.012	-0.154	-0.146	-0.080	1.003
Tree height (m)	1.091	-0.015	-0.138	-0.232	0.018	0.723
Clear bole (m)	1.091	-0.015	-0.138	-0.232	0.018	0.546
Crown length (m)	0.765	-0.013	0.022	-0.266	-0.012	0.496
NOB	-0.555	-0.001	-0.068	0.016	0.202	-0.406

Genotypic residual effect = -0.020 Abbreviation See Table 5 for details

Table 8. Direct and indirect effect of all the independent components on volume using phenotypic correlations

Path using genotypic correlations	DBH (cm)	TH (m)	CBH (m)	CL (m)	NOB	Genotypic correlation with volume
DBH (cm)	0.964	0.093	-0.018	-0.058	0.003	0.984**
Tree height (m)	0.601	0.149	-0.019	-0.104	0.000	0.627**
Clear bole (m)	0.383	0.064	-0.045	0.019	-0.001	0.419*
Crown length (m)	0.414	0.114	0.006	-0.135	0.000	0.401*
NOB	-0.243	0.001	-0.004	0.005	-0.013	-0.255

Phenotypic residual effect = -0.026 Abbreviation See Table 5 for details

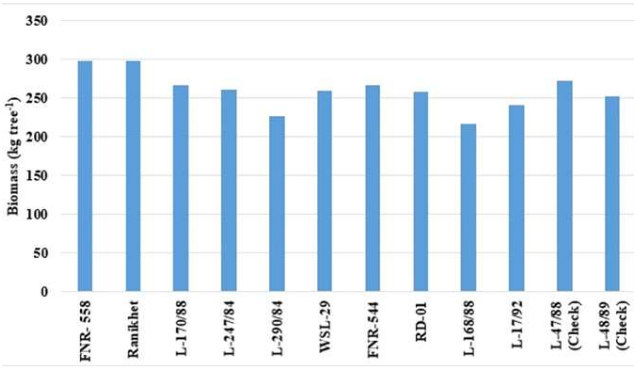

Fig. 1. Variation in biomass (kg tree^{-1}) in clones of *Populus deltoides*

CONCLUSION

The present research indicated noteworthy variations among the poplar clones concerning their growth, allocation of biomass, and nutrient absorption. The research underscores the significance of assessing both genotypic and phenotypic variations among different clones to pinpoint the most promising performers. These outcomes showed practical implications to choose out the best performing clone for commercial plantations in the Punjab state.

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