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Nursery Performance of Male Clones of Poplar (*Populus deltoides* Bartr.) under Temperate Conditions of Kashmir Valley

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Authors' contributions

This work was carried out in collaboration between all authors. Authors AAM and THM designed the study, performed the statistical analysis and wrote the protocol, while the literature search and drafting of the manuscript was managed and done by authors NAM, TAR and PAS. All authors read and approved the final manuscript.

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ABSTRACT

Fifteen (15) male clones of *Populus deltoides* (Twelve clones procured from WIMCO and three local clones) were evaluated in nursery to study their growth performance. The investigations revealed that significant interclonal variation exists for all the selected growth characters. The plant height varied from 179 to 284 cm, collar diameter 17.13 to 27.51 mm, number of branches 3 to 14 and number of leaves 59 to 272 plant^{-1}. The leaf area plant^{-1} also varied between a minimum of 50 to a maximum of 118 cm2 and the internodal length between 3.28 to 5.77 cm. Significant interclonal variation also exhibited in fresh and dry total biomass of seedlings. Based on the morphological growth, the ranking index for these clones was developed and the clones viz., L-34 (TC), L-34 and 65/27 performed best in terms of ranking index with values 133, 126 and 123 respectively. These clones can be used for mass multiplication and for gradual replacement of female cultivars in the Kashmir Valley.

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1. INTRODUCTION

Jammu and Kashmir, a hill state has been growing poplars traditionally. The State grows approximately thirteen to fourteen hundred thousand poplar saplings annually [1]. In Kashmir *Populus* is a bewildering genus with ancient history of traditional cultivation. Besides some prominent native poplars viz., *Populus ciliata and Populus euphratica* the exotic species viz., *Populus nigra* and *Populus deltoides* are domesticated on large scale across the Kashmir valley. Among the two exotic species while, *Populus nigra* was reportedly introduced as an avenue tree around four centuries ago, *Populus deltoides* was introduced by Department of Social Forestry during the year 1984. There are around 15.22 million trees of poplars under different diameter classes with total estimated volume of 5.29 million cubic meters [2]. Around 90 percent of the volume realized from poplars is obtained from the plantation of *Populus deltoides*. The prominent among these clones introduced under the World Bank sponsored project included G3, G48, D67, D75, D82, D121, D161, D171, D181 and L34/82. These clones have been successfully incorporated in many land use systems and are presently spread in every nook and corner of the Valley. The timber obtained from these plantations sustains fruit industry by meeting around 40% of 0.8 to 1.0 million fruit boxes required per annum for exporting the fruit from Kashmir.

Locally misquoted as “Rouse Fras” (Russian Poplar) though native to North America, a major proportion of the plantations of this species in Kashmir are female cultivars. Since main objectives behind cultivation of *Populus deltoides* in Kashmir, are production of timber for construction and making packing crates, the plants of this species are managed for long rotation periods (15-20 years), with the result these plantations attain reproductive phase and produce large quantity of cottony seeds that remain suspended in the atmosphere and hence act as pollutants. Most parts of the Kashmir Valley are affected by this typical cotton storms from poplars during the spring season [1]. The aero allergy from the cottony material leaves the Valley sneezing and coughing ever since it starts dispersal of seeds in the months of April and May [3,4]. This fluffy material also acts as a fire hazard besides hampering the normal life in rural and urban areas of Kashmir [2]. The problem has become so severe from the last few years that there is a large scale public concern to eradicate this species. In the absence of industrial sector that uses juvenile trees, the introduction of fast growing male clones seems to be one of the long lasting solutions to come out of this menace. Keeping in view the problem of female cultivars, the present study was undertaken as a first step to assess the performance of fifteen (15) male clones before their mass propagation can be taken up for large scale plantation across the valley.

2. MATERIALS AND METHODS

The present investigation was carried out at Faculty of Forestry, Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir, Wadura Campus during the year 2012-13 and 2013-14. The experimental site is about 60 km away from summer capital; Srinagar (J&K) located at 34°7′ N longitude and 74°33′ E latitude with an altitude of 1524 m amsl.

The planting of the cuttings was done during February- March 2012. The cuttings were planted following Randomised Block Design with 150 cuttings per clone in three replications (50 cuttings per replicate) at spacing of (60 x 60) cm in sunken beds (each bed representing a particular replicate) of uniform size (300 x 600cm). The cuttings used for sowing were 22 cm long and around 2.0 cm in thickness. All the cultural practices were carried out in the nursery at an appropriate time. Sprouting of each clone was noted weekly till completion. Singling was done in the month of July. Only one promising shoot of each plant was allowed to grow and the additional shoots were detached from the plant with the help of sharp sketchers without causing any splinting damage. Growth trend of best performing clones was evaluated on the basis of sprouting percent, plant height, plant collar diameter, number of branches, number of leaves, leaf area, internodal length, total biomass (fresh & dry), specific gravity and survival percent during the two years of nursery evaluation. Score (1 to 15) was given to each clone in the increasing order on the basis of values obtained with respect to all the selected parameters except number of branches plant^{-1} in which score was given to each clone in the decreasing order of values obtained.The ranking index for various clones was developed after ascribing a performance score to each of the parameters as

per the procedure laid down by Panwar & Sharma [5].

3. RESULTS AND DISCUSSION

3.1 Sprouting and Survival

The clones under investigation exhibited a wide range of sprouting and survival percentage. The data (Table 1) revealed that maximum sprouting of 99.67 was recorded by clone L-34 which was statistically at par with 98.33 by clone L-34(TC). The minimum sprouting percentage 81.00 was recorded by clone G-3. Similarly survival of the seedlings also exhibited similar trend with maximum percentage of 98.83 exhibited by clone L-34 followed by 97.13 by clone L-34(TC). The minimum survival of 87.94 percent was recorded in clone G-3. Variation in sprouting and survival may be attributed to different genetic makeup of clones [5]. Exhibiting a wide range of survival is common when a number of clones are evaluated [6]. The findings regarding variation in survival of clones are in agreement with that of Puri et al. [7]. Rawat et al. [8] reported variation in survival percentage of 75 clones of *Populus deltoides* while evaluating their growth performance in nursery. Chandra & Joshi [9] examined the performance of 32 exotic poplar clones with the survival of 63 to 96 percent. The interclonal variation for survival in *Populus deltoides* has also been reported by [10,11,12].

3.2 Height

The clones under investigation exhibited significant interclonal variation in total height of seedlings and as well as their annual increments (Table 1). Clone L-34 attained a maximum height of 284 cm followed by clone 65/27 with 273 cm. Rank third and fourth was attained by clone W-A/26 and L-34(TC) by attaining plant height of 271 cm and 268 cm. The minimum height of 179 cm was recorded by clone W-108. The local clones viz., LM-1, LM-2 and LM-3 attained rank 11^{th}, 12^{th} and 10^{th} respectively with respect to plant height. The results are in line with Ramesh & Khurana [20]. Nikles, (1963) considered height as the most variable trait at juvenile stage, while as Palmberg, (1977) reported highly significant difference in height growth among 32 clones of *Populus deltoides* in Australia. Variation in height is more due to genetic differences among the clones (Jha et al. 1993; Panwar & Sharma, 2001 [5]).

3.3 Collar Diameter

Value obtained with respect to collar diameter exhibited significant interclonal variation (Table-1). Clone L-34 showed maximum collar diameter of 27.51 mm followed by clone W-A/26 with 25.53 mm. Clone L-34(TC) and 65/27 ranked third and fourth respectively by obtaining collar diameter of 24.94 and 24.79 mm. The minimum collar diameter of 17.13 mm was attained by clone S7C4. The local clones viz., LM-1, LM-2 and LM-3 attained rank 12^{th}, 13^{th} and 10^{th} respectively by obtaining collar diameter of 18.80, 18.46 and 19.64 mm. The results are in agreement with Singh et al. [13] and Dhillon et al. [14] who reported that inherent genetic differences that may be held responsible for the variation in diameter among clones of *Populus deltoides*. Panwar & Sharma [5] reported that 7 clones performed better in terms of their growth among 68 clones in nursery under mid hill conditions of Himachal Pradesh while searching out superior poplar clones. Based on the growth performance during nursery evaluation, Rawat et al. [8] summarized that new clones of *Populus deltoides* show better growth performance in comparison to old ones. Variation in height and diameter may be attributed to climatic and edaphic conditions along with genetic makeup [15].

3.4 Number of Branches Plant^{-1}

Analysis of data (Table-1) revealed significant interclonal variation with respect to number of branches plant^{-1}. While clone W-108 attained rank 1^{st} by obtaining minimum number of 3 branches, the clone L-34 (TC) attained rank 15^{th} by obtaining maximum number of 14 branches plant^{-1}. Clone Udai attained rank 2^{nd} with 5 numbers of branches plant^{-1}. Among locally collected male clones LM-2 exhibited prominent 6^{th} rank by obtaining 7.88 branches plant^{-1}. Singh et al. [16] reported significant differences among 71 clones for morphological growth traits (12 months after planting) viz., plant height, stem diameter and number of branches. Masoodi et al. [17] reported that the clones collected from three ecological blocks exhibited great variation in branch number plant-1. Similarly, significant differences in the number of branches among genotypes of other *Populus species*, including triploid and diploid *Populus* tremuloides clones, have been reported by Burk et al. [18].

Table 1. Growth performance of male clones of *Populus deltoides* (Pooled data of two years)

Sl. no.	Name of clone	Procured from	Origin	Sprouting (%)	Survival (%)	Height (cm)	Collar diameter (mm)	No. of branches plant^{-1}	No. of leaves plant^{-1}	Leaf area (cm^2) plant^{-1}	Internodal length (cm)	Sp. gravity	Total biomass plant^{-1} (g)	
				After 06 weeks									Fresh	Dry
1	G-3	Wimco Seedlings Ltd., Rudrapur, Utranchal	Brazos, Texas (USA)	81.00	87.94	257.67	24.38	5.26	90.59	76.80	4.53	0.415	587.72	231.54
2	W-22		Wimco seedlings Ltd., Rudrapur, Utranchal	90.33	92.56	257.55	23.12	11.54	178.30	81.56	5.03	0.394	1470.88	544.83
3	W-81		Wimco seedlings Ltd., Rudrapur, Utranchal	89.00	94.09	259.13	23.92	8.81	139.52	75.13	3.83	0.411	842.86	351.99
4	W-32		Wimco seedlings Ltd., Rudrapur, Utranchal	92.33	92.56	211.55	20.61	8.69	148.72	67.03	5.77	0.394	825.31	303.27
5	W-A/26		Wimco seedlings Ltd., Rudrapur, Utranchal	95.67	90.83	270.66	25.53	12.27	219.23	91.38	4.38	0.411	1049.53	421.03
6	W-108		Wimco seedlings Ltd., Rudrapur, Utranchal	88.33	89.95	179.21	17.95	2.82	59.03	62.74	3.28	0.399	337.85	128.74
7	S7C4		Brazos, Texas (USA)	90.67	91.15	179.22	17.13	5.60	75.73	49.75	3.98	0.401	355.25	115.44
8	S7C15		Brazos, Texas (USA)	89.67	90.64	185.21	19.00	5.41	104.86	59.19	3.64	0.388	375.60	129.25
9	Udai		Wimco seedlings Ltd., Rudrapur, Utranchal	91.00	92.74	223.67	20.03	4.92	95.50	80.26	4.58	0.403	619.61	222.75
10	65/27		Australia (Canberra)	98.00	96.96	272.96	24.79	12.05	160.58	86.32	5.33	0.400	860.09	328.27
11	L-34(TC)		State Forest Department, Haldwani	98.33	97.13	268.10	24.94	14.30	272.23	117.55	5.13	0.400	1082.63	431.42
12	L-34		State Forest Department, Haldwani	99.67	98.83	283.54	27.51	8.83	164.30	64.28	3.53	0.409	878.73	373.62
13	LM-1	Locally Collected	District Anantnag, J&K	96.33	96.10	187.30	18.80	8.66	67.92	60.38	3.48	0.398	344.92	152.66
14	LM-2		District Anantnag, J&K	95.33	95.59	185.78	18.46	7.88	78.49	59.32	3.53	0.394	338.29	148.13
15	LM-3		District Pulwama, J&K	96.00	95.93	195.12	19.64	9.62	82.26	59.31	3.39	0.396	361.78	153.32
Mean				**92.78**	**93.53**	**227.78**	**21.72**	**8.44**	**129.15**	**72.73**	**4.23**	**0.401**	**688.74**	**269.08**
CD (p ≤ 0.05)				**3.252**	**4.160**	**30.187**	**2.491**	**1.632**	**33.94**	**0.425**	**0.005**	**0.000**	**160.949**	**62.928**
CV (%)				**2.085**	**3.854**	**11.485**	**9.939**	**16.749**	**22.776**	**0.506**	**0.093**	**0.103**	**20.251**	**20.266**

3.5 Number of Leaves & Leaf Area Plant^{-1}

The data in the Table-1revealed significant variation in number of leaves plant^{-1}. Clone L-34 (TC) attained maximum number of 272 leaves plant^{-1} followed by clone W-A/26 with 219 leaves. Minimum number of 59 leaves was exhibited by clone W-108. Significant interclonal variation was also recorded in average leaf area plant^{-1}. During the evaluation clone L-34 (TC) attained maximum leaf area of 118 cm^2 followed by clone W-A/26 with 91 cm^2. Minimum leaf area of 50 cm^2 was exhibited by clone S7C4. A range of clonal variation has been reported for most of the leaf growth parameters [19]. Clonal provenance variation with respect to number of leaves and leaf area collected from three ecological blocks exhibited great variation as has also been reported by Ramesh & Khurana [20] in case of *Populus alba*.

3.6 Internodal Length

The clones under study varied significantly with each other in terms of their internodal length (Table-1). The results revealed that the maximum internodal length of 5.77 cm was obtained by clone W-32 followed by clone 65/27 with 5.33 cm. Rank 3rd was attained by clone L-34 (TC) with length of 5.13 cm. The minimum internodal length of 3.28 cm was exhibited by clone W-108. The results are in line with Ramesh & Khurana [20] who reported the clonal provenance variation of *Populus alba* and found P17 (Tirith) provenance recorded highest internodal length (2.80 cm) and number of leaves (72).

3.7 Specific Gravity

Specific gravity of wood also exhibited interclonal variation (Table-1). Among non-local clones the specific gravity of wood was maximum (0.415) for clone G-3 and minimum (0.388) for clone S7C4. While, locally collected clones LM-1, LM-2 and LM-3 exhibited a wood specific gravity of 0.398, 0.394 and 0.396 respectively. Various studies conducted earlier have indicated high genetic variation in wood specific gravity in *Populus tremuloides* [21], *Populus tomentosa* [22], *Populus deltoides* [23] and *Populus euramericana* [24]. While evaluating 20 clones Rajput et al. [25] reported that as rate of growth varies from clone to clone, variation in specific gravity also occurs.

3.8 Total Biomass (Fresh and Dry) Plant^{-1}

The clones exhibited significant interclonal variation in total biomass plant^{-1} (Table-1). The maximum fresh total biomass of 1471 g plant^{-1} and dry total biomass of 545 g plant^{-1} was attained by clone W-22 followed by clone L-34 (TC) with fresh total biomass of 1083 g plant^{-1} and dry total biomass of 431 g plant^{-1}. The locally collected clones attained fresh total biomass production ranging between 338 to 362 g plant^{-1} and dry total biomass between 148 to 153 g plant^{-1}. On the other hand minimum fresh total biomass of 338 g plant^{-1} and minimum dry total biomass of 115 g plant^{-1} was recorded in clone W-108 and clone S7C4 respectively. Arora et al. [26] reported tree growth parameters and biomass in different tree components increased with age. Genetics plays a role in determining the distribution of mass to leaves, stems, and roots [27]. Karim & Hawkins [28] provided a circumstantial evidence that a genetic basis exists for above and belowground dry mass distribution. According to Kanime et al. [29] the variations in tree biomass are attributed to a number of factors, such as growth conditions, site quality, age, density, structure, and management practices.

3.9 Selection of Best and Potential Male Clones

The results of our study revealed that overall ranking of the clones based on two years of performance clearly indicates that clones of Haldwani origin i.e., L-34 (TC), L-34 and Australian origin i.e., 65/27 performed better than all clones and scored 133, 126 and 123 and were ranked at 1st, 2nd and 3rd position respectively (Table-2). The ranking of these three best clones stayed fairly consistent during both years of study. The other three potential clones viz., W-A/26, W-22 and W-81 of Wimco origin which obtained a score of 119, 105 and 100 ranks were ranked at 4th, 5th and 6th position respectively. The ranking of these three potential clones also remained fairly consistent with only minimal ranking movement for some parameters from first to second year of study. However other clone from Wimco origin i.e., clone W-108 obtained least score of 40 points. The clones of Texas origin i.e., G-3, S7C5 and S7C5 ranked 8th, 13th and 14th respectively. The local clones viz., LM-3, LM-1 and LM-2 secured 65, 64 and 56 points and were respectively at 11th, 10th and 12th rank. Singh and Bangarwa [30] ranked

Table 2. Ranking of male clones of *Populus deltoids*

Sl. no.	Name of clone	Score obtained in terms of											Total score	Rank
		Sprouting (%)	Height (cm)	Collar diameter (mm)	No. of branches plant^{-1}	No. of leaves plant^{-1}	Leaf area (cm^2) plant^{-1}	Internodal length (cm)	Sp. gravity	Survival (%)	Total biomass plant^{-1} (g)			
											Fresh	Dry		
1	G-3	1	10	11	13	6	10	10	15	1	7	8	92	8
2	W-22	5	9	9	4	13	12	12	4	7	15	15	105	**5**
3	W-81	3	11	10	7	9	9	7	14	9	10	11	100	**6**
4	W-32	8	7	8	8	10	8	15	3	6	9	9	91	9
5	W-A/26	10	13	14	2	14	14	9	13	4	13	13	119	**4**
6	W-108	2	1	2	15	1	6	1	7	2	1	2	40	15
7	S7C4	6	2	1	11	3	1	8	10	5	4	1	52	14
8	S7C15	4	3	5	12	8	2	6	1	3	6	3	53	13
9	Udai	7	8	7	14	7	11	11	11	8	8	7	99	7
10	65/27	13	14	12	3	11	13	14	9	13	11	10	123	**3**
11	L-34(TC)	14	12	13	1	15	15	13	8	14	14	14	133	**1**
12	L-34	15	15	15	6	12	7	5	12	15	12	12	126	**2**
13	LM-1	12	5	4	9	2	5	3	6	12	3	5	66	10
14	LM-2	9	4	3	10	4	4	4	2	10	2	4	56	12
15	LM-3	11	6	6	5	5	3	2	5	11	5	6	65	11

15 clones of *Populus deltoides* by carrying out index score method using growth parameters obtained under nursery conditions and found three best and three potential clones among the lot. There are various reports available on ranking of clones based on the comparative performance of clones from nursery studies to the field trials [31,32]. Puri et al. [7] ranked best five clones on the basis of growth and survival after two years.

4. CONCLUSIONS

The different non-local and locally collected male clones of *Populus deltoides,* vary significantly with respect to various growth characteristics viz. sprouting percent, survival of seedlings, progressive seedling height, progressive collar diameter, number of branches plant^{-1}, number of leaves plant^{-1}, leaf area, internodal length, total biomass (fresh & dry) plant^{-1} and wood specific gravity. Among all the clones evaluated under this investigation, three clones viz., L-34 (TC),L-34 and 65/27proved to be best ones. The performance of these three non-local clones was even better than the locally collected ones. These clones can be used for mass multiplication and out planting thereof for gradual replacement of female trees in Kashmir Valley. These clones however need further evaluation and screening under field conditions for growth performance up to the rotation age.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Dhiman RC. Diagnosis of intercrops in poplar based agroforestry in India. Ind. For. 2012;138(7):600-607.
2. Anonymous. Digest of Forest Statistics-2011, J&K Forest Department; 2011.
3. Bhat GM, Singh A, Qasba S, Singh O. Aeroallergens from poplar trees in the Kashmir valley of India, In: International Poplar Commission, 24th Session, Dehradun, India, 30th October-2nd November; 2012.
4. White JF, Levin L, Villareal M, Murphy K, Biogenic R, Wellinghoff L, StClair HG, Bernstein A. Lack of correlation between regional pollen counts and percutaneous reactivity to tree pollen extracts in patients with seasonal allergic rhinitis. Ann. Alle. Asth. Immun. 2005;94(2):240−246.
5. Panwar VP, Sharma R. Nursery performance of exotic poplars under mid-hill conditions of Himachal Pradesh. Ind For. 2001;127(1):44-50.
6. Abrahamson LP, White, EH, Nowak CA, Biggs RD, Robinson DJ. Evaluating hybrid poplar clonal growth potential in a three-year-old genetic selection field trial. Bioma. 1990;21:101-14.
7. Puri S, Swamy SL, Jaiswal AK. The potential of *Populus deltoides* in the sub-humid tropics of Central India: Survival, Growth and Productivity. Ind. For. 2001;127(2):173-186.
8. Rawat GS, Singh NB, Gupta RK, Singh K, Sharma SD. Clonal evaluation of poplar (*Populus deltoides* Bartr.) in eastern Uttar Pradesh. I- Nursery Testing. Ind. For. 2001;127(1):70-80.
9. Chandra JP, Joshi BC. Performance of exotic clones in Tarai (Uttar Pradesh). Ind. For. 1994;120(2):110-118.
10. Verma RC, Bangarwa KS. Inter character correlation studies in *Populus deltoides* Bartr. ex. Marsh. clones under nursery conditions. Ind. J. For. 2005;28:359-362.
11. Ginwal HS, Gera M, Gera N. Genetic variation in seed germination and growth performance of 12 *Acacia nilotica* provenances in India. J. Trop. For. Sci. 2000;12:286-297.
12. Rawat RS, Nautiyal S. Interclonal variation in *Dalbergia sissoo* with respect to growth performance, survival and phonological characteristics in different climatic zones. Ind. For. 2007;**2**:215-226.
13. Singh NB, Kumar D, Rawat GS, Gupta RK, Singh K, Negi SS. Clonal evaluation of poplar *Populus deltoides* in Eastern-UP II-Estimates of genetic parameters in fields testing. Ind. For. 2001;127:163-172.
14. Dhillon GPS, Singh A, Sidhu DS. Performance of poplar (*Populus deltoides* Bartr.) clones under semi-aired conditions of Punjab. Ind. J. For. 2010;33(3):309-311.
15. Khurana DK, Chauhan SK, Mehta A. Genotype and site interaction studies in some promising clones of exotic poplar in Himachal Pradesh. Tree Sci. 1992;11(2): 112-124.
16. Singh NB, Sing B, Kumar D. Genetic analysis of poplar (*Populus deltoids* Bartr.) clones for early generation selection. Ind. J. Gene. 2014;74(4):487-495.

17. Masoodi TH, Ahmad H, Gangoo SA, Sofi PA, Bhat MA, Islam MA. Ecological occurrence of Himalayan poplar (*Populus ciliata* Wallich ex Royle) and its nursery evaluation under temperate conditions of Kashmir. The Bioscan. 2014;9(2):585-588.
18. Burk TE, Nelson ND, Isebrands JG. Crown architecture of short-rotation, intensively cultured *Populus*. III. A model of first-order branch characteristics. Canad. J. For. Res. 1983;13:1107-1116.
19. Marron N, Villar M, Dreyer E, Delay D, Boudouresque E, Petit JM, Delmotte FM, Gueh JM, Brignolas F. Diversity of leaf traits related to productivity in 31 *Populus deltoides* × *Populus nigra* clones. Tree Physio. 2005;25:425–435.
20. Ramesh RK, Khurana DK. Clonal provenance variation of *Populus alba* Linn. in nursery. Ind. J. For. 2008;31(4): 599-610.
21. Yanchuk AD, Dancik BP, Micko MM. Variation and heritability and wood density and fibre length of trembling aspen in Alberta, Canada. Silv. Geneti. 1984;33(1): 11-16
22. Song W, Zhang ZY, Xu JR. Study on inheritance and variation of wood basic density of *Populus tomentosa* Carr. Clones. J. Beiji. For. Uni., 1997;6(1):8-18.
23. Zhang QW, Su XH, Li JH, Chen YS, Xie HF. Studies on collection, preservation and genetic valuation of genetic resources of *Populus deltoides* Bartr. Scient. Silv. Sin. 1999;35(2):31-37.
24. Beaudoin M, Hernandez RE, Koubaa A, Poliquin J. Interclonal, interaclonal and within tree variation in wood density of poplar hybrid clones. Wood Fib. Sci. 1992;24(2):648-656.
25. Rajput SS, Shukla NK, Khanduri AK. Studies on variation of specific gravity and comprehensive strength of different clones of *Populus deltoides*. Van Vigy. 1997; 35(3&4):165-171.
26. Arora G, Chaturvedi S, Kaushal R, Nain A, Tewari S, Alam NM, Chaturvedi OP. Growth, biomass, carbon stocks, and sequestration in an age series of *Populus deltoides* plantations in Tarai region of central Himalaya. Turki. J. Agri. For. 2014;38:550-560.
27. Poorter H, van Rijn CPE, Vanhala TK, Verhoeven KJF, de Jong YEM, Lambers H. A genetic analysis of relative growth rate and underlying components in *Hordeum spontaneum*. Oecolo. 2005;142: 360–377.
28. Karim SA, Hawkins BJ. Variation in response to nutrition in a three-generation pedigree of Populus. Canad. J. For. Res. 1999;29:1743-1750.
29. Kanime N, Kaushal R, Tewari SK, Raverkar, KP, Chaturvedi S, Chaturvedi OP. Biomass production and carbon sequestration in different tree-based systems of Central Himalayan Tarai region. For. Trees Liveli. 2013;22**:**38–50.
30. Singh R, Bangarwa KS. Evaluation of various clones of *Populus deltoides* for root and shoot characters under nursery conditions. Ind. J. For. 2006;29(1):79-83.
31. Mishra KK, Rai PN, Jaiswal HR. Performance of Poplar (*Populus deltoides*) clones under Tarai conditions of Uttar Pradesh. Ind. For. 1995;121(12):1155-1157.
32. Singh RP, Negi DV. Performance of exotic poplars under nursery conditions in Himachal Pradesh. Ind. For. 1996; 122(2):122-127.

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