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Amit Singhdoha
Department of Forestry, CCS Haryana Agricultural University, Hisar, Haryana India

KS Bangarwa
Department of Forestry, CCS Haryana Agricultural University, Hisar, Haryana India

Vishal Johar
Department of Forestry, CCS Haryana Agricultural University, Hisar, Haryana India

BK Hooda
Department of Maths and Statistics, CCS Haryana Agricultural University, Hisar, Haryana, India

RS Dhillon
Department of Forestry, CCS Haryana Agricultural University, Hisar, Haryana India

Correspondence
Vishal Johar
Department of Forestry, CCS Haryana Agricultural University, Hisar, Haryana India

Assessment of general volume table for *Populus deltoides* in northern Haryana

Amit Singhdoha, KS Bangarwa, Vishal Johar, BK Hooda and RS Dhillon

Abstract
Populus deltoides is an important agroforestry tree species adopted by the farmers in North India. The economic returns are comparatively better than rice-wheat rotation under well managed conditions. The presented investigation was carried out in the Yamunanagar district of Haryana state. The data on tree height, diameter at breast height was recorded on 91 randomly selected trees having diameter at breast height (1.37 m from surface) ranging from 14.2 to 35.4 cm. The trees were felled and cut into logs of acceptable merchantable lengths. The trees were felled and cut into logs of acceptable merchantable lengths. The data on log length, log diameter on both ends and at mid-point, and log weight were recorded. The volume regression equations were developed to predict the volume table on basis of diameter at breast height (DBH) and tree height, and DBH alone. Results were statistically analysed and found that all equations had very good-fit. Using R^2 as the indicator of best fit, the model proposed by Schumacher and Hall (R^2 = 0.941) was found the most appropriate to predict volume for poplar plantation in Haryana. Single-entry model (R^2 = 0.902) was also recommended for predication of volume as it is not always easy to measure accurate height of the standing tree. These tables will be useful to the farmers, timber growers, wood contractors, state forest departments, research workers and the planners in their respective areas of concern for future plantation programmes.

Keywords: *Populus deltoides*, poplar, volume table, DBH

Introduction
Poplar (*Populus deltoides*) is now widely grown all over northern India and is considered as the most suitable agroforestry tree because of its desirable characteristics and multiple uses. It is widely grown on a rotation of six to eight years in northern India *viz.* Punjab, Haryana, Uttrakhand, U.P. and Bihar. A well-drained, deep and fertile soil is suitable for poplar. Poplar prefers neutral soils, but can be grown well on soils having pH from 5.5 to 8.0. It is successfully planted only under irrigated conditions and success is restricted to correct choice of clone, spacing and better management practices. G3, G48, L34, S7C15, Uday, Kranti and Bahar are superior clones of poplar that are suitable for the different agroclimatic conditions of northern Indian states like Punjab, Haryana, Uttar Pradesh and Uttrakhand. WIMCO Seedlings Ltd., Rudrapur (Uttrakhand) has got registered six new clones of *Populus deltoides viz.* WSL-22, WSL-27, WSL-32, WSL-39, WSL-A26 and WSL-A49 with the International Poplar Commission of FAO, Italy (Bangarwa, 2007) [1]. The clones were released for commercial planting during 2002. These clones attain commercial size girth of about 1.0 m in 6 years under good management practices.
The timber volume tables are useful and essential to estimate the sale price of standing trees. Several timber volume tables developed in the past for this species (Lohani and Sharma, 1977; Sharma, 1979; Chaturvedi, 1984; Dhanda and Verma, 2001) [7, 9, 2, 4] are from other states and locality. As the farmers have taken up poplar cultivation in a big way, they are curious to know the quantity of their produce and want to know an estimate of their standing tree crop and return from its sale before final decision about its marketing. But they have no tools available to make such an estimate. Neither the State Forest Department nor the private wood based industries like Western India Match Company (WIMCO) have developed such tools. Therefore, keeping in view, the present investigation was carried out to develop volume table on basis of DBH and tree height and DBH alone for the species.

Materials and Methods
The present investigation was carried out in the Yamunanagar district (77º 28' E longitude and 30º 1' N latitude and elevation is 255 m (837 ft) above m.s.l. The mean monthly temperature of Yamunanagar ranges from 6.8 ºC in January to 39.4 ºC in summer months of May and June. The Yamunanagar region has maximum area under poplar plantation in Haryana.

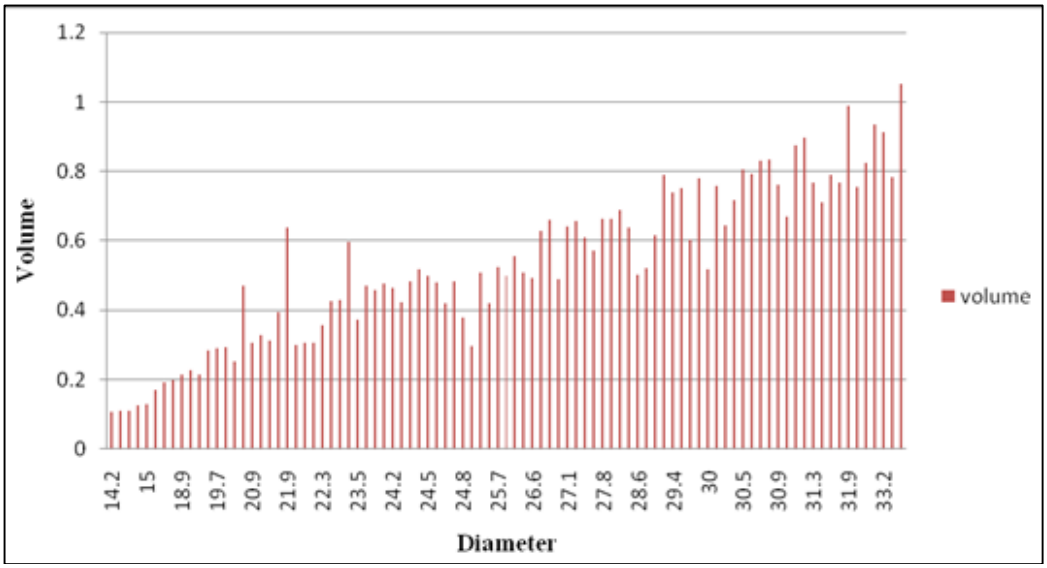
The Yamunanagar region is biggest timber market for trees grown under agro-forestry systems. Due to various forest based industries, like those of plywood and paper, Yamunanagar has provided the tree growers a ready market for a variety of tree species especially Poplar and Eucalyptus.

Trees with all possible DBH and height were selected for recording the data by visiting felling site in Yamunanagar district. The felled sample trees were measured for diameter at breast height (DBH), total tree height and merchantable bole height. Direct measurements on diameter at breast height (DBH) at 1.37m from ground level, total tree height, and merchantable bole height were taken after trees were felled. Felled trees were pruned to clear lateral branches along with lops and tops. Uprooted stump portion of felled trees were cut and main bole were cut into 2.59 m and 1.29 m sections upto a top diameter of 10 cm (over bark). Diameters at both ends of each section were recorded and mean diameter was calculated. Volume calculated for each section of a tree. Volume of all sections was summed up to know total timber volume over-bark.

The regression models were fitted with the observed and estimated values for volume and a simultaneous F test was performed for the intercept and slope. Evaluation of the goodness of fit of models was performed by calculating the coefficient of determination, residual mean square and standard error of estimate. For multi entry regression equations, the diameter (DBH) squared times tree height (D^2H) was used as independent variable as described by spurr (1952) in "combined variable" method. For single entry tables, only DBH was used as an independent variable. For regression form, the equations were used are given in table 1.

Results and Discussion

Trees with all possible DBH and height were selected for recording the data by visiting felling site in Yamunanagar district. Ninety one trees were randomly selected for recording actual volume and weight corresponding to diameter at breast height (DBH). Actual volume and weight corresponding to DBH were used for development of volume table. The trees diameter at the breast height varies from 14.2 cm to 35.4 cm. The actual volume of trees corresponding to diameter at breast of the trees is graphically presented in Figure 1.



Timber volume: In general, tree volume is estimated using volume equations that provide a volume estimate from simple measurements such as diameter at a height of 1.37 m, total height or height to fork and some expression of tree form (Clutter *et al.*, 1983; Finger, 1992; Friedl *et al.*, 1991; Prodan *et al.*, 1997) [3, 5, 6, 8]. These equations may be local (when volume is a function of a single variable such as *d*) or standard (when volume is a function of two or more variables, usually d and h). We have used four different regression equations to estimate the timber volume, out of which three for standard timber volume and one for local timber volume. Lohani and Sharma (1997), Sharma (1979) [9], Chaturvedi (1984) [2] and Dhanda and Verma (2001) [4] have developed volume and weight tables for *P. deltoides* based on data from states other than Haryana.

Table 1: Regression equation for timber volume estimation of *P. deltoids*

Model Name	Regression equation	Coefficient of Determination (R^2)	Standard error
Combined variable	$V = 0.0543+0.00003D^2H$	0.906	0.069
Generalized combined variable	$V=0.112+0.0035H+0.0075D+0.000024D^2H$	0.908	0.069
Logarithmic (Schumacher and Hall)	$V= 0.0000964H^{0.892}D^{1.785}$	0.941	0.130
Single-entry	$\sqrt{V} = -0.1006+0.0316D$	0.902	0.052

Standard timber volume

(a) Combined variable Model: In this model, the variables diameter (D) and height (H) are used combined (D^2H) as one variable. Coefficient of determination (R^2) and standard error of estimate are respectively 0.906 and 0.069 as given in table 1. About 90.6% of variation in the character timber volume is explained by the variation in the character D^2H. This shows that the estimation of timber volume using this regression equation is quite near to actual volume. Based on the above regression equation, the estimated table for green timber volume is given in table 2.

Table 2: Standard timber volume table for *P. deltoiodes* based on $V= 0.0543 + 0.00003D^2H$

DBH\H	12	14	16	18	20	22	24	26	28	30
14	0.126	0.138	0.150	0.162						
16	0.148	0.164	0.179	0.195	0.211	0.226	0.242			
18	0.173	0.193	0.213	0.232	0.252	0.272	0.292			
20	0.201	0.225	0.250	0.274	0.299	0.323	0.348	0.372		
22	0.232	0.261	0.291	0.320	0.350	0.380	0.409	0.439		
24	0.265	0.301	0.336	0.371	0.406	0.442	0.477	0.512		
26	0.302	0.343	0.385	0.426	0.468	0.509	0.550	0.592	0.633	
28		0.390	0.438	0.486	0.534	0.582	0.630	0.678	0.726	0.774
30			0.495	0.550	0.605	0.660	0.715	0.770	0.825	0.880
32				0.618	0.681	0.743	0.806	0.869	0.931	0.994
34					0.761	0.832	0.903	0.974	1.044	1.115
36						0.926	1.006	1.085	1.164	1.244
38							1.114	1.203	1.291	1.379
40								1.327	1.425	1.523

(b) Generalized combined variable: As given in table 1, Coefficient of determination (R^2) for this regression equation is 0.908 and standard error of estimate is 0.069. About 90.8% of variation in the character timber volume is explained by the variation in the characters H, D and D^2H. This model is prepared by using variables height (H), diameter (D) and a combined variable (D^2H). Combined variable model and generalized combined variable show very high variation in the characters. Hence, both the models are very good fit to estimated timber volume. Based on this regression equation, the estimated table for timber volume is given in table 3.

Table 3: Standard timber volume table based on $V=0.112+ 0.0035H + 0.0075D + 0.000024D^2H$

DBH\H	12	14	16	18	20	22	24	26	28	30
14	0.092	0.109	0.125	0.142	0.158					
16	0.124	0.144	0.163	0.183	0.202	0.221	0.241			
18	0.159	0.182	0.204	0.227	0.250	0.272	0.295			
20	0.196	0.222	0.249	0.275	0.301	0.327	0.354	0.380		
22	0.235	0.265	0.296	0.326	0.356	0.387	0.417	0.448		
24	0.277	0.311	0.346	0.381	0.416	0.450	0.485	0.520		
26	0.320	0.360	0.400	0.439	0.479	0.518	0.558	0.597	0.637	
28		0.411	0.456	0.501	0.545	0.590	0.635	0.680	0.724	0.769
30			0.516	0.566	0.616	0.666	0.717	0.767	0.817	0.868
32				0.634	0.691	0.747	0.803	0.859	0.916	0.972
34					0.769	0.832	0.894	0.957	1.019	1.082
36						0.921	0.990	1.059	1.129	1.198
38							1.090	1.167	1.243	1.319
40								1.279	1.363	1.447

(c) Logarithmic or Schumacher and Hall Model: For this regression model, Coefficient of determination (R^2) is 0.941 and standard error of estimate is 0.130 (as given in table 1). About 94.1% of variation in the character timber volume is explained by the variation in the characters D and H. The value of determination coefficient being quite high (R^2=0.94) implies that this estimates fresh green timber volume of poplar very near to the actual. Based on the above regression equation, the estimated table for green timber volume is given in table 4. Standard timber volume of poplar trees of 22 cm DBH varied from 0.221 to 0.440 m^3 depending upon the tree height variation from 12 m to 26 m (Table 4). The tree having height of 24 m and 36 cm DBH contain volume of 0.987 m^3. The standard timber volume ranged from 0.098 to 1.453 m^3 per tree (Table 4).

Table 4: Standard timber volume table for *P. deltoiodes* based on $V= 0.0000964H^{0.892}D^{1.785}$

DBH\H	12	14	16	18	20	22	24	26	28	30
14	0.098	0.113	0.127	0.141	0.155					
16	0.125	0.143	0.162	0.179	0.197	0.215	0.232			
18	0.154	0.177	0.199	0.221	0.243	0.265	0.286			
20	0.186	0.214	0.241	0.267	0.294	0.320	0.345	0.371		
22	0.221	0.253	0.285	0.317	0.348	0.379	0.410	0.440		
24	0.258	0.296	0.333	0.370	0.407	0.443	0.478	0.514		
26	0.297	0.341	0.384	0.427	0.469	0.511	0.552	0.593	0.633	
28		0.389	0.439	0.487	0.535	0.583	0.630	0.677	0.723	0.769
30			0.496	0.551	0.606	0.659	0.713	0.765	0.818	0.869
32				0.618	0.679	0.740	0.800	0.859	0.917	0.976
34					0.757	0.824	0.891	0.957	1.022	1.087
36						0.913	0.987	1.060	1.132	1.204
38							1.087	1.167	1.247	1.326
40								1.279	1.366	1.453

Local timber volume: In practice, it is not always easy to measure total height of each standing tree, which is both time consuming and cumbersome. Therefore, regression equation of timber volume based on DBH alone was also worked out.
Single-entry Model: As shown above in table 1, Coefficient of determination (R^2) is 0.902 and standard error of estimate is 0.052. About 90.2% of variation in the character timber volume is explained by the variation in the character D. Volume table based on this regression equation is given in Table 5.

Table 5: volume table for *P. deltoiodes* based on $\sqrt{V} = -0.1006 + 0.0316D$

DBH (cm)	Volume (m^3)
14.0	0.1172
15.0	0.1398
16.0	0.1645
17.0	0.1912
18.0	0.2198
19.0	0.2505
20.0	0.2832
21.0	0.3178
22.0	0.3545
23.0	0.3932
24.0	0.4338
25.0	0.4765
26.0	0.5212
27.0	0.5679
28.0	0.6166
29.0	0.6672
30.0	0.7199
31.0	0.7746
32.0	0.8313
33.0	0.8900
34.0	0.9507
35.0	1.0134
36.0	1.0781
37.0	1.1448
38.0	1.2134
39.0	1.2841
40.0	1.3568

The results showed that for estimating timber volume of poplar trees, the DBH alone can also be relied upon, as per significance of coefficient of determination (R^2). It implies that we can estimate the volume of total timber with the regression equation based on DBH alone. The single-entry equation is recommended by Dhanda and Verma (2001) [4] and Tewari (2007) [11] also, as it is not always easy to measure accurate height. However more reliable estimate of tree volume over wider area can be obtained from the regression equation based on both tree height and DBH, as the tree height is better of site characters while the DBH is influenced by planting density. The coefficient of determination (R^2) in case of Schumacher and Hall model (0.941) is relatively higher than those of single-entry model (0.902).
The fitted volume equations presented provided good estimation of the volume of individuals of *Populus deltoides*. Using R^2 as the indicator of best fit, the model proposed by Schumacher and Hall was found the most appropriate to predict volume for poplar plantation in Haryana. Tewari (2007) [11] reported that Schumacher and Hall model was fittest model for predicting the volume of *Tecomella undulate*. Mathematical expressions of the model to estimate total volume were $V=aH^{b1}D^{b2}$, where V is total volume (m^3), H is the height (m) and D is the diameter at a height of 1.37 m (cm).

Timber volume and Timber weight relationship
The wood based industries are generally interested in the weight of raw material either green or dry (Sharma 1979) [9]. To facilitate 0direct conversion of poplar timber volume to timber weight, a relationship between the two has been worked out. The details of the statistical analysis of weight-volume relationship are given below:
$\sqrt{W} = 26.713(V)^{0.503}$
Coefficient of determination (R^2) = 0.996
Standard error of estimate = 0.007
With an increasing emphasis on complete tree biomass utilization and the use of wood as a resource of energy, equation and tables are needed to know the total green weights of whole trees inclusive of components such as bole wood, branches, foliage, etc.

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