TIMBER VOLUME AND WEIGHT TABLES OF FARM-GROWN POPLAR (*POPULUS DELTOIDES* BARTR. EX MARSH.) IN PUNJAB (INDIA)

R.S. DHANDA* AND R.K. VERMA**

Introduction

Intensive farm forestry requires that foresters/ farm tree growers are able to estimate tree volume accurately for such phases of timber management as timber sales, advance planning, growth and yield studies (McDonald and Skinner, 1989). The Poplar *(P. deltoides)* is being raised in Punjab as a fast growing tree species yielding high timber volume at a relatively short rotation. Its wood is well - suited to industries such as match-splints, pulp and paper, plywood, fibre-board etc. (Sharma, 1979). The farmers in the State are following a short rotation of 6-7 years as the trees attain marketable size at that age and thus reduce the gestation period of final return from Poplar trees.

As the farmers have taken up Poplar cultivation in a big way, they are curious to know the quality and quantity of their produce and want to have 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. However, Lohani and Sharma (1977), Sharma (1979), and Chaturvedi (1984) have developed volume and weight tables for *P. deltoides* based on data from States other than Punjab, these do not, therefore, represent agroforestry conditions in Punjab. The present study was aimed at to have an answer to the problem. So timber volume (both overbark and underbark), fresh green timber weight, above ground biomass, total wood (bole wood + stump wood) weight and firewood estimate regressions were developed and tables were prepared from data derived from 71 felled trees.

Study area

A large number of farm forestry plantations of *P. deltoides* clone G3 were available in the central districts of the State. For the present study Poplar plantations in the district of Ludhiana (75° 40' E longitude and 30°45' N latitude) were selected. The elevation of Ludhiana is 244 m above m.s.l. The mean monthly temperatures range from 5.8° C in January to 41.2° C in summer months of May and June. A greater portion (70 to 75%) of the total rainfall is received as summer monsoon in the months from July to mid-

* Professor, Deptt. of Forestry & Natural Resources, Punjab Agricultural University, Ludhiana (Punjab)
**Forest Range Officer, Jammu & Kashmir Forest Department, Jammu (J&K)

September. About 80 per cent of the area of the State receives a total rainfall of 300 mm to 800 mm (Sehgal *et al.,* 1992).

In the present investigation, to construct the single-entry (local) and multi-entry (standard) timber volume, weight and other tables, the data were collected when the harvesting of block plantations of Poplar at a spacing of 4m x 5m was in progress at two locations, namely, Nurpur Khaira Bet (Site-1) and Raneke (Site-2) in Ludhiana District. At both sites, trees were planted in January-February 1986 and harvested in October 1991, and April, 1992, respectively. Thirty trees at Site-1 and 41 at the other location were measured for volume, weight and other tree measurements. Trees were felled manually clear felling the field with stumps removed simultaneously.

Material and Methods

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 and the lops and tops. Thinner branches of diameter less than 10 cm and deformed branches were graded as firewood and were weighed. Lops and tops were weighed immediately to minimize the loss due to transpiration. Uprooted stump portions of felled trees were cut and main boles were cut into 2.64 m and 2.03 m sections up to a top diameter of 10 cm (over bark) at two sites, respectively. Diameter at both ends of each section was recorded and mean diameter was calculated. Each section was then weighed on a weighing scale. Weights of all sections of a tree were summed up. Similarly, volume calculated for all sections of a tree was summed up to know total timber volume over-bark. The bark thickness at both ends of each log was also recorded to calculate the timber volume under bark and the percentage of bark with respect to timber volume over bark and under bark. At Site-2, weights of stumps of felled trees were also taken to calculate total wood (bole + stump) weight.

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 taken as an independent variable.

For regression equations, following forms were used :

Multi-entry table : $Y = a + b * D^2 H$,
Single-entry table : $\sqrt{Y} = a + b * D$

Where,
Y = dependent variable, such as timber volume, timber weight, etc.
D = diameter at breast height (DBH) in metres.
H = total tree height in metres, and
a and b are regression constant and regression coefficient, respectively.

Regression equations of the above forms were fitted to the data. The data were processed in the Statgraph program on computer in the Department of Forestry & N.R. Four models namely: linear, multiplicative, exponential and reciprocal were employed to choose the one which explained the greatest proportion of variability in the timber volume and weight in Poplar trees.

Actual and computed figures of each tree were compared and these were found

to be quite close. Details of various relationships and their statistical analysis are given below :

Following symbols have been used in this paper :

Wg = Green timber weight (over bark) in kg/tree
Vob = Timber volume over bark in m^3 /tree
Vub = Timber volume under bark in m^3/tree
Ybio = Above ground biomass yield in kg/tree
Yfw = Firewood yield in kg/tree
Ytw = Total wood weight in kg/tree

Results and Discussion

1. *Timber volume over bark (Vob)*

(a) *Standard timber volume (ob)* : Poplar are usually sold in the local markets and at mill-gate as round timber with bark. Using co-efficient of determination (r^2) as the indicator of best fit, the linear model was chosen for constructing the standard timber volume (ob) table.

The regression equation is :

Vob = 0.00703 + 0.32224 * D^2 H
Correlation coefficient (r) = 0.9823
Standard error of estimate = 0.0293

Analysis of variance (ANOVA) for standard timber volume (ob) of *P. deltoides* is given in Table 1a.

About 96.5 % of variation in the character timber volume (ob) is explained by the variation in the character D^2 H. Figures based on this regression equation are given in Table 1b.

(b) *Local timber volume (ob)* : 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 (ob) based on DBH alone were also worked out.

The regression equation of V ob on DBH is :

Vob = 4.9058 $(DBH)^{1.45847}$
Correlation coefficient (r) = 0.9754
Standard error of estimate = 0.0839

Table 1a

Analysis of variance (ANOVA) for standard timber volume (ob) of P. deltoides

Source of Variation	df	Sum of Squares	Variance	Variance ratio (F) Obs.	Variance ratio (F) Exp. 0.1%	Coeff. of det. (r^2)
Linear Regression	1	1.62745	1.6274	1900.97***	11.80	0.9650
Residual	69	0.05907	0.000856			
Total	70	1.686503				

*** Significant at 0.1% level of probability.

Table 1b

Standard timber volume (ob) table for P. deltoides based on Vob = 0.00703 + 0.32223 D^2H (m^3/tree)

DBH	Tree height (m)							
(cm)	10	14	18	22	24	26	28	30
10	0.039	0.052	0.065					
15	0.080	0.108	0.138					
20	0.136	0.188	0.239	0.291	0.316			
22	0.163	0.225	0.288	0.350	0.381			
24	0.193	0.267	0.341	0.415	0.453	0490		
26		0.312	0.399	0.486	0.530	0.573		
28		0.361	0.462	0.563	0.613	0.664	0.714	0.765
30			0.529	0.645	0.703	0.761	0.819	0.877
32			0.601	0.733	0.799	0.865	0.931	0.997
34			0.677	0.827	0.901	0.976	1.050	1.125
36				0.926	1.009	1.093	1.176	1.260
38					1.124	1.217	1.310	1.403
40					1.244	1.347	1.451	1.554

n = 71 felled trees.
Standard error of regression coefficient = 2.02926
Determination coefficient = 0.9650

Table 1c

Analysis of variance (ANOVA) for local timber volume (ob) of P. deltoides

Source of Variation	df	Sum of Squares	Variance	Variance ratio (F)		Coeff. of det. (r^2)
				Obs.	Exp. 0.1%	
Linear Regression	1	9.4938	9.4938	1349.80***	11.80	0.9574
Residual	69	0.485309	0.007033			
Total	70	9.979068				

*** Significant at 0.1% level of probability.

Analysis of variance (ANOVA) for local timber volume (ob) of *P. deltoides* is given in Table 1c.

A large proportion of the variation (>95%) in the character timber volume (ob) is explained by the variation in the character DBH alone, therefore the measurement of height of Poplar trees can be safely dispensed with as there is only marginal gain from 95.7% to 96.5%. Figures based on this regression are given in Table 6.

2. ***Timber volume under bark (Vub)*** :

(a) *Standard timber volume (ub)* : For estimating the timber volume under bark (Vub) the linear model gave the best fit (r^2 = 0.9662). The regression equation of volume (ub) on D^2 H is :

V ub = 0.003487 + 0.268366 * D^2H
Correlation coefficient (r) = 0.9829
Standard error of estimate = 0.0239

Analysis of variance (ANOVA) for timber volume (ub) for *P. deltoides* is given in Table 2a.

Figures of timber volume (ub) based on this equation are tabulated in Table 2b.

(b) *Local timber volume under bark (Vub)*: The multiplicative model of the form $\sqrt{Y} = a * x^b$ gave the best fit (r^2 = 0.95) for estimating timber volume (ub) on the basis of DBH alone.

The regression equation is :

$\sqrt{Vub} = 4.472243\ (DBH)^{1.46276}$
Correlation coefficient (r^2) = 0.9745
Standard error of estimate = 0.08566

Analysis of variance for local timber volume (ub) of *P. deltoides* is given in Table 2c.

About 95% of variation in timber volume (ub) is explained by the character tree DBH alone and figures are given in Table 6.

3. Green Timber Weight :

Poplar timber is usually sold by farmers by weight in nearby timber markets or at the mill-gate delivery basis. Therefore, they will like to know the fresh timber weight (biomass) produced by standing tree crop. Rather than converting timber volume to weight through wood density, it was scientifically preferred to weigh a series of sample trees and to relate tree-weight to measurable tree dimensions like DBH and tree height through regression analysis similar to those for volume prediction (Avery and Burkhart, 1983). The wood based industries especially the plywood industry requires the Poplar wood raw material in fresh green condition. Therefore to have an estimate of standing timber for plywood industry, the weight measurements of freshly cut trees up to 10

Table 2a

Analysis of variance (ANOVA) for timber volume (ub) for P. deltoides

Source of Variation	df	Sum of Squares	Variance	Variance ratio (F)		Coeff. of det. (r^2)
				Obs.	Exp. 0.1%	
Linear Regression	1	1.1288	1.1288	1971.89***	11.80	0.9662
Residual	69	0.039498	0.000572			
Total	70	1.163279				

*** Significant at 0.1% level of probability.

Table 2b

*Standard timber volume (under bark) table for P. deltoides based on Vub = 0.003487 + 0.268366 * D^2H (m^3 / tree)*

DBH	Tree height (m)								
(cm)	10	14	18	20	22	24	26	28	30
10	0.030	0.041	0.052	0.057					
15	0.064	0.088	0.112	0.124					
20	0.111	0.154	0.197	0.218	0.240	0.261			
22	0.133	0.185	0.237	0.263	0.289	0.315			
24	0.158	0.220	0.282	0.313	0.344	0.374	0.405		
26		0.258	0.330	0.366	0.403	0.439	0.475		
28		0.298	0.382	0.424	0.466	0.508	0.551	0.593	0.635
30			0.438	0.486	0.535	0.583	0.631	0.680	0.728
32				0.553	0.608	0.663	0.718	0.773	0.828
34				0.624	0.686	0.748	0.810	0.872	0.934
36					0.769	0.838	0.908	0.977	1.047
38						0.933	1.011	1.088	1.166
40						1.034	1.120	1.206	1.292

n = 71 felled trees.
Standard error of regression coefficient = 0.02393
Determination coefficient = 0.9662

Table 2c

Analysis of variance for local timber volume (ub) of P. deltoides

Source of Variation	df	Sum of Squares	Variance	Variance ratio (F)		Coeff. of det.
				Obs.	*Exp. 0.1%*	(r^2)
Linear Regression	1	9.5497	9.5497	1301.4996***	11.80	0.9497
Residual	69	0.506285	0.007357			
Total	70	10.055995				

*** Significant at 0.1% level of probability.

cm over bark were taken. With this viewpoint, weight tables (both standard and local) for green timber estimation have also been developed.

(a) *Standard green timber weight (Wg)*: Of the four models tested, the multiplicative model gave the best fit ($r^2 = 0.97$) for the recorded data.

The regression equation is :

$Wg = 268.806 (D^2 H)^{0.976581}$
Correlation coefficient (r) = 0.9831
Standard error of estimate = 0.146148

Analysis of variance for green timber weight of *P. deltoides* is given in Table 3a.

The value of determination coefficient being quite high ($r^2 = 0.97$) implies that this equation estimates the fresh green timber weight of Poplar very near to the actual. Based on the above regression equation, the estimated figures for green timber weight are given in Table 3b.

(b) Local Green timber weight (Wg) : In this case DBH alone can be employed and the trouble to measure the total tree of standing trees can be avoided. Of the four models tested, multiplicative model gave the best fit for the data.

$\sqrt{Wg} = 154.4561 (DBH)^{1.51944}$
Standard error of estimate = 0.092883
Correlation coefficient (r) = 0.9726

Analysis of variance for local green timber weight of *P. deltoides* is given in Table 3c.

Figures based on above regression equation are given in Table 6.

4. Timber volume and weight relationship :

The wood-based industries are generally interested in the weight of raw material either green or dry (Sharma, 1979). To facilitate direct conversion of Poplar timber volume to weight a relationship between the two has also been worked out. The details of the statistical analysis of weight-volume relationship are given below :

$\sqrt{Wg} = 862.513 (Vob)^{1.03602}$
Correlation coefficient = 0.9932
Standard error of estimate = 0.093022

With an increasing emphasis on complete tree biomass utilization and the use of wood as a resource of energy, equations and tables are needed to know the total green weights of whole trees inclusive of components such as bole wood, branches, foliage, etc.

ANOVA for timber volume and weight relationship of *P. deltoides* is given in Table 4.

Table 3a

Analysis of variance for green timber weight of P. deltoides

Source of Variation	df	Sum of Squares	Variance	Variance ratio (F)		Coeff. of det. (r^2)
				Obs.	Exp. 0.1%	
Linear Regression	1	41.9643	41.9643	1964.70***	11.80	0.9665
Residual	68	1.45240	0.021359			
Total	69	43.416719				

*** Significant at 0.1% level of probability.

Table 3b

Standard green timber weight for P. deltoides based on $Wg = 268.806\ (D^2H)^{0.976581}$ *(kg / tree)*

DBH	Fresh Timber weight (kg/tree) Tree height (m)								
(cm)	10	14	18	20	22	24	26	28	30
10	28.4	39.4	50.4	55.8					
15	62.6	87.0	111.2	123.2	135.3				
20	109.8	152.6	195.0	216.2	237.3	258.3			
22	132.3	183.8	234.9	260.4	285.8	311.1	336.4		
24	156.8	217.9	278.5	308.6	338.8	368.8	398.8		
26	183.4	254.7	325.6	360.9	396.1	431.2	466.2	501.2	536.2
28	211.9	294.4	376.3	417.2	457.8	498.4	538.9	579.3	619.7
30		336.9	430.6	477.2	523.8	570.2	616.6	662.9	709.1
32		382.1	488.4	541.4	594.2	646.9	699.4	751.9	804.3
34			549.8	609.4	668.9	728.2	787.4	846.5	905.5
36					747.8	814.2	880.4	946.4	1012.4
38						904.9	978.4	1051.8	1125.2
40						1002.2	1081.5	1162.7	1243.7

n = 70 felled trees.
Standard error of regression coefficient = 0.146148
Determination coefficient = 0.9665

Table 3c

Analysis of variance for local green timber weight of P. deltoides

Source of Variation	df	Sum of Squares	Variance	Variance ratio (F) Obs.	Exp. 0.1%	Coeff. of det. (r^2)
Linear Regression	1	10.2675	10.2675	1190.13***	11.80	0.9466
Residual	68	0.586653	0.008627			
Total	69	10.85414				

*** Significant at 0.1% level of probability.

As high as 98.6 per cent of the variation in the fresh green timber weight is explained by variation in the character timber volume (o b), green timber weight can, therefore, be calculated from timber volume over bark.

5. Biomass yield :

(a) *Standard fresh biomass* : Total biomass yields by Poplar trees are important for scientific and ecological studies to estimate

Table 4

ANOVA for timber volume and weight relationship of P. deltoides

Source of Variation	df	Sum of Squares	Variance	Variance ratio (F)		Coeff. of det. (r^2)
				Obs.	Exp. 0.1%	
Linear Regression	1	42.8283	42.8283	4949.5011***	11.80	0.9864
Residual	68	0.588403				
Total	69	43.416719				

*** Significant at 0.1% level of probability

Table 5a

Analysis of variance of standard fresh biomass yield of P. deltoides

Source of Variation	df	Sum of Squares	Variance	Variance ratio (F)		Coeff. of det. (r^2)
				Obs.	Exp. 0.1%	
Linear Regression	1	6.91645	6.91645	398.73***	13.61	0.9366
Residual	27	0.468348	0.017346			
Total	28	7.384803				

*** Significant at 0.1% level of probability.

total productivity. The standard fresh biomass yield regression giving the best fit came to be as follows :

$\sqrt{Y}$ bio = 446.2067 $(D^2H)^{0.74941}$
Correlation coefficient = 0.9678
Standard error of estimate = 0.131705

Analysis of variance of standard fresh biomass yield of *P. deltoides* is given in Table 5a.

Figures based on the above regression equation are given in Table 5c.

(b) *Local Fresh Biomass* : For local fresh biomass estimation DBH alone was used as an independent variable and the multiplicative model gave the best fit.

Regression equation worked out as :

$\sqrt{Y}$ bio = $129.3097(DBH)^{1.21435}$
Correlation coefficient = 0.9683
Standard error of estimate = 0.06533

Analysis of variance of local fresh biomass yield of *P. deltoides* is given in Table 5b.

Figures based on the above regression equation are given in Table 6.

Table 5b

Analysis of variance of local fresh biomass yield of P. deltoides

Source of Variation	df	Sum of Squares	Variance	Variance ratio (F)		Coeff. of det. (r^2)
				Obs.	Exp. 0.1%	
Linear Regression	1	1.73097	1.73097	405.57***	13.61	0.9376
Residual	27	0.115235				
Total	28	1.346202*				

*** Significant at 0.1% level of probability.

Table 5c

Standard fresh biomass yield table for P. deltoides based on $\sqrt{Y} = 466.2057\ (D^2H)^{0.74941}$ *(biomass yield kg/tree)*

DBH	Tree height (m)								
(cm)	10	14	18	20	22	24	26	28	30
10	83.0	106.8	129.0	139.6					
15	152.4	196.2	236.8	256.3	275.2				
20	234.6	301.9	364.5	394.4	423.6	452.2			
22	270.6	348.3	420.4	455.0	488.7	521.6	553.8		
24	308.3	396.8	479.0	518.4	556.7	594.2	631.0		
26		447.4	540.1	584.4	627.7	670.0	711.4	752.0	
28		499.9	603.5	653.1	701.4	748.7	795.0	840.4	885.0
30			669.2	724.2	777.9	830.3	881.6	931.9	981.4
32			737.2	797.8	856.9	914.6	971.1	1026.6	1081.1
34				873.7	938.4	1001.6	1063.5	1124.3	1183.9
36					1022.3	1091.2	1158.6	1224.8	1289.8
38					1108.6	1183.3	1256.4	1328.2	1398.7
40						1277.9	1356.9	1434.3	1510.4

n = 28 felled trees with stumps.
Standard error of regression coefficient = 0.131705
Determination coefficient = 0.9366

6. ***Firewood yield*** **:**

Similarly, regression equations for estimating firewood and total timber yield (bole wood + stump wood) were also worked out and are given as follows :

(a) Standard equation for firewood estimation came out to be :

$Yfw = 28.912 + 52.132 * D^2H$
Correlation coefficient (r) = 0.9432
Determination coefficient (r^2) = 0.8896
Standard error of estimate = 9.3452

(b) Local equation for firewood came out to be :

$\sqrt{Yfw} = 0.77625 + 36.8877 * D$
Correlation coefficient (r) = 0.9224
Determination coefficient (r^2) = 0.8508
Standard error of estimate = 0.6617

7. ***Total wood yield*** :

Similarly, standard equation for total wood (bole + stump) weight worked out as:

$\sqrt{Wtw} = 286.8645 (D^2H)^{0.936825}$
Correlation coefficient (r) = 0.9774
Determination coefficient (r^2) = 0.9553
Standard error of estimate = 0.14198

While local equation for total wood weight worked out as :

$\sqrt{Wtw} = 124.7623 (D)^{1.37889}$
Correlation coefficient (r) = 0.9753
Determination coefficient (r^2) = 0.9513
Standard error of estimate = 0.07413

8. ***Percentage of bark volume*** :

Average percentage of bark volume of both over bark and under bark timber volumes for *P. deltoides* clone 'G-3' was found to be 18.46 and 22.64 per cent,

Table 6

Local table for timber volume (o.b.) and (u.b.), fresh timber weight and above ground fresh biomass for P. deltoides

DBH (cm)	Volume (ob) (m^3)	Volume (ub) (m^3)	Fresh timber wt. (kg)	Fresh total biomass (kg)
10	0.029	0.024	21.8	62.3
15	0.095	0.078	74.8	166.6
20	0.220	0.180	179.3	335.5
22	0.291	0.238	239.5	422.9
24	0.375	0.308	312.0	522.4
26	0.473	0.389	398.0	634.5
28	0.587	0.483	498.4	759.6
30	0.718	0.591	614.7	898.1
32	0.867	0.713	747.9	1050.6
34	1.035	0.852	899.1	1217.2
36	1.222	1.007	1069.7	1398.5
38	1.431	1.180	1260.7	1594.7
40	1.662	1.370	1473.4	1806.3

respectively. Chaturvedi (1984) also reported a similar bark volume percentage for this clone G-3 to be 18.13 and 22.15 per cent, respectively from Tarai area of Uttar Pradesh. It was found out that percentage of bark volume varied with the size of Poplar trees, i.e., thicker the logs lesser the bark percentage and vice versa.

9. ***Specific gravity of Poplar wood*** :

Besides determining the relationship between timber volume and timber weight, specific gravity of freshly cut Poplar wood was also worked out. Samples were taken from four different diameter classes to calculate mean specific gravity.

Specific gravity of Poplar fresh timber is given in Table 7.

Table 7

Specific gravity of poplar fresh timber

Diameter classes (cm)	Specific gravity
10-15	0.735
15-20	0.810
20-25	0.850
25-30	0.865
Average	0.806

It is evident from the table that the specific gravity increased with diameter growth. Average specific gravity was found to be 0.81.

10. ***Checking applicability of volume and weight tables*** :

Even though the regression equations developed for timber volume, timber fresh weight, and fresh biomass yield based on destructive sampling of trees were highly statistically significant, the comparison of measured and estimated values was still made to check the applicability of timber volume (overbark), and fresh timber weight tables as suggested by Husch *et al.*, (1982). They suggested that the aggregate difference of measured and estimated values of a test sample should not exceed $2CV\sqrt{n}$, where CV is the coefficient of variation of the table being tested , and 'n' is the number of trees used in the test. The comparison of various tables is given below:

(a) *Timber volume (ob) table* : The comparison of measured and estimated timber volumes (ob) is given the Table 8 and aggregate difference between measured and estimated timber volumes is found to be - 0.39% which does not exceed $2CV\sqrt{n}$ i.e., $2\ (66.2)\sqrt{71} = 15.74\%$.

It clearly indicates that the timber volume (ob) table is applicable for use in the field without correction.

(b) Timber volume (ub) table : This table is also applicable as such in the field since the aggregate difference in the measured and estimated timber volume (ub) is 0.38 %, which does not exceed $2*CV/\sqrt{n}$ i.e., $2(66.9) / \sqrt{71} = 15.9$ % (Table 9).

(c) *Fresh timber weight (Wg) table* : The measured and estimated fresh timber weights were also compared for sample trees following Husch *et al.* (1982) and their aggregate difference (+ 1.27 %) was less than $2.CV/\sqrt{n}$. (i.e., 16.4 %) which confirms the applicability of fresh timber weight table for use in the field as such, Table 10.

(d) *Total biomass (Y bio) table* : Similarly, since the aggregate per cent difference

Table 8

Comparison of measured and estimated timber volumes (ob) of test sample trees of P. deltoides (vol. ob m^3)

DBH class (cm)	Sample trees (no.)	Measured volume	Estimated volume	Aggregate diff. (%)
7-10	1	0.0164	0.0219	- 33.5
10-13	3	0.1259	0.1274	- 1.19
13-16	17	1.5808	1.6489	- 4.31
16-19	12	1.7546	1.6951	+ 3.51
19-22	14	3.4110	3.3186	+ 2.78
22-25	17	5.8017	6.0012	- 3.44
25-28	5	2.5419	2.4605	+ 3.31
28-31	2	1.2892	1.3110	-1.85
All classes	71	16.5215	16.5866	- 0.39
Coefficient of variation (CV) = 66.2 %		n = 71		

Table 9

Comparison of measured and estimated timber volume (u b) of test sample trees of P. deltoides (vol. ub m^3)

DBH class (cm)	Sample trees (no.)	Measured vol.	Estimated vol.	Aggregate diff. (%)
7-10	1	0.0133	0.0159	- 19.55
10-13	3	0.1008	0.0986	+ 2.23
13-16	17	1.2770	1.3329	- 4.38
16-19	12	1.4256	1.3832	+ 3.07
19-22	14	2.7883	2.6795	+ 4.06
22-25	17	4.7820	4.9576	- 3.67
25-28	5	2.0884	2.0373	+ 2.49
28-31	2	1.0668	1.0889	- 2.07
All classes	71	13.5422	13.5939	- 0.38
Coefficient of variation (CV) = 66.9%		n = 71		

between measured and estimated biomass is only -3.49% which is much lower than $2CV/\sqrt{n} = 2(38.96)/\sqrt{29} = 14.5\%$, (Table 11) and coefficient of variation is 38.96%, the biomass yield Table 6 can also be used without any correction.

The accuracy of these tables can be further improved by incorporating data of more trees. The sample trees employed in

Table 10

Comparison of measured and estimated fresh timber weights of sample trees of P. deltoides (kg/tree)

DBH class (cm)	Sample trees (no.)	Measured wt.	Estimated wt.	Aggregate diff. (%)
7-10	1	11.5	13.4	- 16.52
10-13	3	91.5	96.8	- 7.76
13-16	17	1290.2	1313.3	- 1.79
16-19	11	1294.5	1291.2	+ 0.26
19-22	14	2813.5	2653.9	+ 6.01
22-25	17	4779.1	4897.2	- 2.41
25-28	5	2147.7	2003.0	+ 7.22
28-31	2	1076.1	1065.8	+ 0.97
All classes	70	13504.1	13334.6	+ 1.27
Coefficient of variation (CV)= 68.5 %		n = 70		

Table 11

Comparison of measured and estimated biomass of sample trees of P. deltoides (kg/tree)

DBH class (cm)	Sample trees (no.)	Measured biomass	Estimated biomass	Aggregate diff. (%)
7-10	0	-	-	-
10-13	1	80.7	68.2	+ 18.33
13-16	2	313.0	397.2	- 26.90
16-19	1	325.1	309.7	+ 4.97
19-22	8	2848.8	2944.6	- 3.36
22-25	11	5386.9	5739.2	+ 6.54
25-28	4	2711.9	2649.1	+ 2.37
28-31	2	1554.0	1573.8	- 1.27
All classes	29	13220.4	13681.8	- 3.49
Coefficient of variation (CV) = 38.96%,		n = 29 trees felled for total biomass.		

the preparation of these tables came from the central district of Ludhiana in Punjab. Observations from other areas where poplars are being grown in agroforestry systems need to be taken and standard timber volume and weight tables can be prepared for use all over the State. Moreover data needs to be collected for age, diameter class distribution, and yield of various Poplar plantations so that decision on financial rotation, economic spacing and optimal utilization can be taken.

Acknowledgements

The authors would like to thank the farmers who cooperated with us in the collection of data when Poplar trees were being felled in their fields. Thanks are also due to the Head of the Department of Forestry & Natural Resources for providing laboratory facilities and encouraging us in taking up agroforestry related research problem dealing with estimation of timber volume and weight of standing Poplar trees.

SUMMARY

Timber volume and weight tables have been prepared for Poplar *P. deltoides*, which is an important agroforestry tree species in Punjab and is grown mainly for commercially important industrial timber. Timber volume (both over bark and under bark), fresh timber weight, above ground biomass, and firewood estimate tables have been developed based on regression equations. Of four simple regression models tested for single-entry and multi-entry regression equations, linear and multiplicative models of the form $Y = a + b^x$, and $Y = a*x^b$, respectively, provided the best fit to the observed limits of data. Applicability of multi-entry tables was checked through statistical analyses and were found to be applicable without correction. Percentage of bark volume (over bark and under bark timber volume) for clone G-3 was found to be 18.5 and 22.6 per cent, respectively. The specific gravity of green wood came out to be 0.806.

पंजाब (भारत) के फार्मों में उगाए जा रहे *पोपुलस डेल्टायडिस* बार्ट्र० *निषेध* मार्श की प्रकाष्ठ आयतन और भार सारणियां

आर०एस० ढांडा व आर०के० वर्मा

साराशं

पोपलर, *पोपुलस डेल्टायडिस* के प्रकाष्ठ की आयतन और भार सारणियां तैयार की गई हैं, जो कि पंजाब में उगाई जा रही महत्वपूर्ण कृषिवानिकी वृक्ष जाति है और प्रधानत: महत्व वाले व्यापारिक प्रकाष्ठ की तरह उगाई जाती हैं । प्रकाष्ठ आयतन (सवल्क और अवल्क दोनों), ताजे हरे प्रकाष्ठ का भार, भूमि से ऊपर का जैवपुंज और जलाऊ काष्ठ की अनुमान सारणियां प्रतीयापन समीकरणों के आधार पर विकसित की गई हैं । एकल प्रविष्टि और बहुल-प्रविष्टि प्रतीयापन समीकरणों के लिए परीक्षित किए गए सरल चार प्रतीपायन मॉडलों में से क्रमश: $y = a + b^x$ और $y = a^* x\ b$ रूप वाले रेखीय और गुणित मॉडल से आंकड़ों की प्रेक्षित सीमाओं के लिए सर्वोत्तम ठीक रहने वाले मॉडल प्राप्त हुए । बहुल-प्रविष्टि सारणियों की प्रयोज्यता की जांच पड़ताल सांख्यिकीय विश्लेषणों द्वारा करके देखी गई और वे बिना कोई संशोधन कराए प्रयोज्य रहती पाई गई । जी3 कृन्तक में छाल के आयतन का प्रतिशत (छाल के ऊपर और छाल के नीचे के प्रकाष्ठ आयतन का) क्रमश: 18.5 और 22.6% रहता पाया गया । हरे काष्ठ का आपेक्षिक गुरूत्व (या भार) 0.806 रहा ।

References

Avery, T.E. and H.E. Burkhart (1983). *Forest Measurements.* Third edition. McGraw-Hill Book Company, New York. 331 pp.

Chaturvedi, A.N. (1984). Volume tables of *Populus deltoides* clones G3, G48 and IC. *U.P. Forest Bull. No. 49.* 16 pp.

Husch, B., C.I. Miiler and T.W. Beers (1982). *Forest Mensuration*. John Willey & Sons, New York. 402 pp.

Lohani, D.N. and R.P. Sharma (1977). Regional volume tables for Poplar *(Populus deltoides)* (Based on data of U.P.). *Indian Forester*, **103**(12) : 818-821.

McDonald, P.M. and C.N. Skinner (1989). Local volume tables for young growth conifers on a high quality site in the northern Sierra Nevada. Pacific Southwest Forest and Range Experiment Station, Forest Service, US Department of Agriculture,Berkeley, Ca., *Res. Note PSW-404*. 6p.

Sehgal, J., M.S. Bajwa and P.K. Sharma (1992). Soils of Punjab. *Research Bull*. National Bureau Soil Survey *Publ. 31*. 122 pp.

Sharma, R.P. (1979). Weight and Volume tables and Volume-Weight relation for Poplar *(Populus deltoides). Indian Forester* **105** (7) : 509-512.

Spurr, S.H. (1952). *Forest Inventory*. Ronald Press, New York. pp.205-370.

Verma, R.K. (1993). Studies on Growth and Performance of *Populus deltoides* Bartr. in Punjab. *M.Sc. Thesis* submitted to Punjab Agricultural University, Ludhiana. 154 pp.+ xi.