ISSN 1110-0419

Annals Of Agric. Sc., Moshtohor,
Vol. 44(3): 1025-1035, (2006).

CONSTRUCTING FRESH WEIGHT TABLE FOR *Eucalyptus Camaldulensis* DEHN. TREES GROWN AT NORTHERN FOREST PLANTATION

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ABSTRACT

In view of the increasing economic importance of wood of *Eucapyptus* trees especially in paper factories, fresh weight table were formulated by using biometrics techniques and statgraph program in the computer. During September 2001 data about height, diameter at breast height, and weight of 123 trees of *Eucalyptus camaldulensis* growing in Dibis forest plantation were utilized for the above purpose, the data were subjected to intensive regression and correlation analysis for developing the intended relationship.

In evaluation different models, several measures of precision including standard error of mean, coefficient of determination and the test of overall unbiasedness of estimates were used to screen the set of equations for selecting the best one to be adopted for constructing a particular table. From 22 simple, 4 stepwise and 6 curvilinear regression equations resulted in the selection of stepwise regression equation:

$$W = 6690.775 - 7791.0113 \log d + 1262.822 \sqrt{d} - 9058.146\ 1/\sqrt{d}$$

It gave the best fit as compared to the other equations, it has standard error for the mean 8.869 with coefficient of determination (R^2) 0.9991, therefore a fresh weight table prepared upon that equation in which the diameter only is the independed variable. Because of presence many precise equations in this study, its possible to prepare other type of tables including height as independent variable or height and diameter together.

INTRODUCTION

Eucalyptus camaldulensisi Dehn., has the widest natural distribution in the world of any Eucalyptus (Chippendale and Wolf, 1981 and Apsey and Reed, 1996). It is one of the fastest-growing species in terms of height, diameter and tree volume (King and Krugman, 1980). It occupies nearly 85 percent of the plantations of northern of Iraq (Majid, 1979).

Estimates of fresh or dry weight biomass for individual trees and tree component are of interest to managers and policymakers. Dimensional analysis as described by Whittaker and Woodwell is the method used most often by foresters and ecologists to predict individual tree biomass. This method relies on the consistency of an allometric relationship between plant dimensions – usually diameter at breast height (d.b.h) and/or height and biomass for a given species, group of species, or growth form. Using the dimensional analysis approach, a researcher samples many stems spanning the diameter and/or height range of interest, and then uses a regression model to estimate the relationship between one or more tree dimensions (as independent variables) and tree-component weights (as dependent variables), (Jennifer *et al.*, 2004).

To achieve this end, procedures and techniques proposed by Chaturvedi and Venkatraman, 1973 to develop regression equations of green weight with bark and air-dry weight without bark for *Eucalyptus* hybrid, in South India, from these equations, the prepared two way weight tables by tree diameter and total tree height, and Kushalappa, 1984 construct a regression equation and tables for above ground dry weight in relation to diameter at breast height and total height, based on samples a 12 years old plantation of *Eucalyptus tereticornis*. Also Attiwill and Ovington, 1968 prepared regression equations for estimating the dry weight of merchantable stem, roots, foliage using regression mode: ($\text{Log } w = a + b \text{ Log } d$). While Zhang *et al.*, 1984 recommended this equation: ($Wt = a + bd + cd^2$) as relation between the weight (Wt) and diameter (d) for artificial *Cunninghamia lanceolata* forest.

There were many studies carried on the trees of *Eucalyptus* at Dibis forest plantation in Iraq concerned about the yield in shape of age-volume relationships (Majid, 1979), diameter distribution (Younis, 1973) and about technological properties of the wood, especially about specific gravity (Suleiman, 1981).

In view of the increasing economic importance of this species and to facilitate judicious sale and purchase of *Eucalyptus* wood between forestry stations and paper factories, the present study aimed formulating fresh-weight tables by using biometric techniques using as far as possible objective methodology in their production so that unbiased and precise estimates of the dependent variables are obtainable. And these tables would will prove to be considerable value in the economic evaluation of stands of this species, thus the tables enable making right management decisions in the long run.

Location and site description :

Dibis forest plantation is situated on the right bank of the Lower Zab river at northern of Iraq, Kirkuk city if 50 Km from plantation toward south west. The altitude is 313 m with mean annual precipitation 383.1 nm, Kirkuk is categorized as a sub-tropical semi-arid and hot region in accordance with Koppn's system of climate classification. The soil is alluvial formed by periodic depodition and erosion during various stages of river flooding. Generally, it is sandy loam with its depth varying from 0.2 to 3.5 m (Raeder – Riotzsch, 1969).

MATERIAL AND METHODS

During September 2001, 123 trees of *Eucalyptus camaldulensis* well distributed over the area and covering the most of diameter ranges were cut at 30 cm above the ground in the Dibis forest plantation. The diameter of these trees ranged from 4.1 to 41.2 cm and the height from 4.36 to 31.25 m (Cockerham, 2004).

Individual trees diameter were measured at breast height (d.b.h.) by diameter tape, after felling each tree, its height was measured by metallic tape to the tip of the leading shoot. Immediately following it, the green weight of merchantable stem of each tree was scaled on unequal arm balance. Due care was taken to keep/down the loss of moisture content by solar radiation to the minimum the weight measured correctly to one decimal place of Kilograms (Kg).

In the present study, only mathematical models form the basis of all work done on the construction of a number of trees biometry tables for *Eucalyptus camaldulensis*. As many regression equation had to be developed and compared in order to select the best one from each set of equations, the data were processed on the computer using statgraph program to handle simple, multiple regression equations and to handle the stepwise regression procedure.

Measures of precising of regression function :

Loetsch *et al.*, 1973 have given a comprehensive discussion of the criteria used for judging the suitability of individual test equations. The most important among these are the coefficient of determination, the standard error of estimate (Draper *et al.*, 1966).

Kozak 1976 observed that coefficient of determination could not be used as index when comparing several equations such as parabolic and logarithmic equation, mainly because the range in independent variables and slope of the regression lines changed from one equation to another (Barrett, 1974). However, according to Kozak the best approach was to calculate and compare the residual variation after back transformation of the dependent variables to original units.

Ohtomo, 1956 developed a simple test to evaluate overall unbiasedness of estimates from any equation throughout the range of basic data, he assumed the regression model, $\hat{Y} = n + mY$. According to this model if the actual value of the dependent variable agreed with that of its estimated value, the $\hat{Y}$ will be equal to Y and all points will lie on a straight line at 45 degrees to both axes. Under such a hypothesis of lime at 45 degrees to both axes. Under such a hypothesis of $\hat{Y} = Y$, "n" should be equal to zero and "m" equal to one therefore, any equation with values of "n" and "m" very close to zero and one respectively would be adjudged superior in performance to others as it would yield unbiased estimates throughout the range of data.

Criteria of best fit :

The following criteria were employed in evaluating the screening different functions tested in the study with a view to finally selecting the one which gave the best fit:

(I). Standard error of estimate (S.E.): Is the etimated deviation of the error, it measures the amount of variability in the dependent variable not explained by the estimated model.

(II). Coefficient of determination (R^2): *It calculated by system (statgraph)* by the computer after any transformation has been preformed for dependent variable.

(III). Test of unbiasdeness of estimates throughout the range of data was suggested by Ohtomo, 1956.

(IV). Compatible with above criteria given in (I), (II) and (III), performance was given to the equation which has a few independent variables.

RESULTS AND DISCUSSIONS

Relationship between height and diameter :

By using SPPS program six methods of expression (Linear, logarithmic, inverse, Exponential, Quadratic and Cubic) were adopted in order to select strongest relationship between the diameter at breast height (d.b.h.) as independent variable and the height of *Eucalyptus* trees as dependent variable (Table 1). The results showed that all of the methods except inverse method closely correlation coefficient of determination (R^2) ranged from (0.810 – 0.852) but we can choose the linear regression equation: h = 5.662 + 0.5077 d because its higher (R^2) – 0.852 and simplicity.

Table (1):Shows regression equations in six methods of expression between the height and (d.b.h.) with R^2 values.

	Methods	Equations	R^2
1	**Linear**	$H = 5.6620 + 0.5077\ d$	0.852
2	**Logarithmic**	$H = -10.629 + 9.4421\ Ln\ (d)$	0.830
3	**Inverse**	$H = 24.734 - 114.72\ l/d$	0.685
4	**Exponential**	$H = 7.585 + exp\ (0.0323\ d)$	0.810
5	**Quadratic**	$H = 4.996 + 0.5844\ d - 0.0016\ d^2$	0.843
6	**Cubic**	$H = -3.0307 + 2.1025\ d - 0.0777\ d^2 + 0.0011\ d^3$	0.851

Simple regression equation :

Twenty-two regression equations were developed using this procedure. In the process of developing the equations, the dependent variable used were W and log W with (11) variables (d, d^2, $\sqrt{d}$, 1/d, $1/d^2$, $1/\sqrt{d}$, $1/\sqrt{d}$, log d, h, 1/h, 1/h, $\sqrt{h}$, log h), the developed regression equations with their measures of reliability are given in Table (2).

2. Stepwise variable selection :

The stepwise variable selection procedure works in essentially the same manner as the multiple regression procedure, except that it allows use to use either a forward or backward selection procedure to control the entry of variables into the model.

In each step of the procedure variables are entered or removed with the goal of obtaining a model with a small set of significant variables.

The procedure may be helpful in building a model when we have a large number of possible independent variables and are unsure which to include.

Table (2): Shows simple regression equations with their respective measures of precision.

EQ. No.	Regression equations	R^2	S.E. of estimate	S^E
1	W = -224.8823 + 33.44175 d	0.9560	60.994	-
2	W = -108020 + 0.48727 d^2	0.9960	18.312	-
3	W = -623.3682 + 253.595 √d	0.8839	99.081	-
4	W = 578.6039 – 3890.122 1/d	0.4776	210.232	-
5	W = 958.9150 – 2653.988 1 √d	0.6256	177.973	-
6	W = 414.8945 – 0.000121 1/d^2	0.2582	250.508	-
7	W = -848.167 + 906.3305 log d	0.7699	139.501	-
8	W = -371.683 + 37.1648 h	0.8457	114.233	-
9	W = 637.6376 – 4541.914 1/h	0.4500	215.704	-
10	W = -852.728 + 278.3448 √h	0.7662	140.627	-
11	W = -889.3021 + 980.570 log h	0.6488	172.632	-
12	Log W = -0.590 + 2.1729 log d	0.9963	0.03747	17.821
13	Log W = -0.76831 + 2.4146 log h	0.8856	0.20735	97.315
14	Log W = 1.8807 + 0.00485 d	0.9229	0.17020	71.465
15	Log W = 0.63492 + 0.08477 h	0.9906	0.05930	26.531
16	Log W = 1.60562 + 0.000905 d^2	0.7739	0.29150	162.615
17	Log W = 0.12134 + 0.45/6 √d	0.8669	0.22358	112.781
18	Log W = 2.93726 – 11.0477 1/d	0.8669	0.22358	112.781
19	Log W = 3.87306 – 6.92082 1/√d	0.9576	0.12624	60.725
20	Log W = 2.50820 – 40.0353 1/d^2	0.6351	0.37032	186.513
21	Log W = -0.6105 + 0.66959 √h	0.9981	0.02649	16.434
22	Log W = -0.76831 + 2.4146 log h	0.8856	0.20735	101.659

The forward procedure begins with no variables in the model and adds one at a time as long as the new variable adds significantly to the model. It also checks at each stage to see that previously selected variables are still significant variables that become insignificant are removed.

The backward procedure begins with a model containing all the variables and eliminates them one at a time. In this procedure the system may re-enter variables into the model that were removed if they later would add significantly to the fit.

The stepwise selection for w and log w with two selection procedures (forward and backward) was shown in Table (3) as a final selection of models.

3. Simple curvilinear regressions :

The simple curvilinear regression procedure fits a model relating one dependent variable to one independent variable by minimizing the sum of squares of the residuals for the fitted line, any of three models can be fitted.

* Multiplicative $y = a x^b$
* Exponential $y = c^{a+bx}$
* Reciprocal $1/y = a + bx$

Table (3):Shows stepwise regressions equations with their respective measures of precision.

EQ. No.	Selection method	Regression equations	R^2	S.E. of estimate	S^E
1	Forward	$W = -10.8023 + 0.48727\, d^2$	0.9960	18.312	-
2	Backward	$W = 6690.775 - 7791.10113 \log d + 1262.822 \sqrt{d} - 9058.146\ 1\text{-}\sqrt{d}$	0.9991	8.869	-
3	Forward	$\text{Log } W = -0.61059 + 0.66959 \sqrt{h}$	0.9981	0.0265	16.434
4	Backward	$\text{Log } W = -1.4238 + 504595\ 1/h - 0.79156 \sqrt{h} - 10.8096\ 1/d^2$	0.9990	0.0191	9.732

In the multiplicative and exponential models, "Linearization" is achieved through logarithmic transformation the model parameters are estimated in the reciprocal model and Table (4) show the result of non-linear regression equations between weight (in original form w and transformed form log w) as dependent variables and diameter (d) as independent variable.

Table (4):Nonlinear models of regression for weight (y) with diameter (x) with their respective measures of precision.

(A)-w with d REG. No	Models	Intercept	Slope	R^2 of estimate	S.E	S.E^
1	**Multiplicative** $y= ax^b$	-1.3498	2.17039	99.62	0.08676	22416
2	**Exponential** $y = \exp(a+bx)$	2.5092	0.11162	92.31	0.39094	92.469
3	**Reciprocal** $1/y=a+bx$	0.05797	-0.00172	44.24	0.02352	29.773
(B) – log w with d						
4	**Multiplicative**	-0.75302	0.50454	97.92	0.04766	22.831
5	**Exponential**	0.17349	0.24733	89.376	0.13879	73.911
6	**Reciprocal**	1.08049	0.51779	67.60	0.11523	58.723

Selection procedure :

From Table (1) appears 22 regression equation, (11) of them were in original form, whereas the remaining equations it was transformed into log w. The standard errors of these two sets of equations were not directly comparable, while the first set had the standard error in the represented in log units, the residual variation was calculated after back transformation of the dependent variable to the original units.

This in turn enabled the calculation of standard error of the mean (S.E^), these statistics have been shown in Table (1).

In the first set of equations R^2- values ranged from 0.4500 to 0.9981 and S.E from 16.434 to 250.508 therefore the equation No. 2 subjected to further analysis to chick for unbiasedness of estimate throughout the range of data, and in the second set of equations (12-22) the equation No. 21 subjected to further analysis and the remaining equations were discarded because it has relatively higher S.E and less R^2 – values.

In Table (2) there are (4) stepwise regression equation selected by two procedures (forward and backward) for original form of weight (w) and transformed form (Log w). It seems that transformations of diameter as independent variables will related and selected with (w) when it was in original form and the height (h) as independent variable appeared with logarithmic form (Log w).

The R^2 – values were very close one to another at the four equations but standard error of estimate (S.E) ranged from 8.86 – 18.312, in backward procedure the (S.E) were less than the forward procedure so equation No. 2 and 4 selected for further analysis.

The nonlinear regression models (multiplicative, exponential and reciprocal) for w and log w appeared in Table (3). The equation in exponential and reciprocal models gave lower value of correlation coefficient as compared with multiplicative model. The equation No. 1 was selected for further analysis.

The five contesting equation were subjected to further analysis to check for unbiasedness of estimates throughout the range of data were :

1. $w = -10.8023 + 0.48727\ d^2$
2. $\text{Log } w = -0.61059 + 0.66959 \sqrt{h}$
3. $w = 6690.775\text{-}0113 \log d + 1262.822 \sqrt{d} - 9058.146\ 1/\sqrt{d}$
4. $\text{Log } w = -1.4238 + 5.4595\ 1/h - 0.79156\ h - 10.8096\ 1/d^2$
5. $w = -1.3498 {*}\ d^{2\,170039}$
6. $\text{Log } w = -1.3498 + 20170039 \log d$

This was accomplished by establishing a relationship Wij = n+m wij. Where w^ij is the estimated weight of jth tree obtained with I th equation the calculated simple regression coefficients "n" and "m" are shown for these equations in Table (5).

Table (5): Tree weight equations number showing test of unbiasdeness.

EQ. Number	"n"	"m"
1	0.8818	0.9415
2	0.9539	1.0090
3	0.2979	0.9991
4	0.9989	1.0001
5	1.0293	0.9900

However as the "n" and "m" values for equation 3 were closest to 0 and 1 as compared to all other equation, therefore equation 3 was finally selected for adoption (Fig. 1). In developing the finally selected regression:

$$W = 6690.775 - 7791.0113 \log + 1262.822 \sqrt{d} - 9058.146\ 1/\sqrt{d}$$

The weight – diameter table for *Eucalyptus camaldulensis* was presented in Table (6).

Table (6): Diameter-weight table for *Eucalyptus camuldulensis* Dehn.

Diameter at breast height (cm)	Estimated weight (kg)	Diameter at breast height (cm)	Estimated weight (kg)
5	18.086	24	275.421
6	23.948	25	302.203
7	24.772	26	330.102
8	25.593	27	356.906
9	26.668	28	386.765
10	28.749	29	415.654
11	34.462	30	445.259
12	42.172	31	475.560
13	52.871	32	505.925
14	65.231	33	537.511
15	79.738	34	569.666
16	96.372	35	600.832
17	114.858	36	633.472
18	133.364	37	666.028
19	154.208	38	697.847
20	176.736	39	730.487
21	200.022	40	763.423
22	224.067	41	796.528
23	249.375	42	830.707

(1) Derived from:
$W = 6690.775 - 7791,0113 \text{ Log } d + 1262.822 \sqrt{d} - 9058.146\ 1/\sqrt{d}$

(2) Standard error or estimate S.E = 8.869

(3) Coefficient of determination $R^2 = 0.9991$

According to Ohtomo, 1956 and McNob and Clark 1982, the actual values of weight and predicted values form developed and adopted equation (No. 3) presented in Fig. (1) after drawing the straight line devoted from error at angle 45°C, shows the predicted values very close to the fitted line and that refers the precise of the chosen equation.

The scatter diagram the finally adopted equation showing the plot of residuals and presented in Fig. (2) the diagram did not show any discernible trend of the relationship, indicating that the model adopted described the weight-diameter relationship quit adequately (Lovenstien *et al.* 1993).

In this study there are another parameter of tree have been studied and that was the height, if there is the height measurements only the equation No. 2: ($\log w = -0.61059 + 0.66959 \sqrt{h}$) allow to represent or to prepare the weight – height table in a precise result.

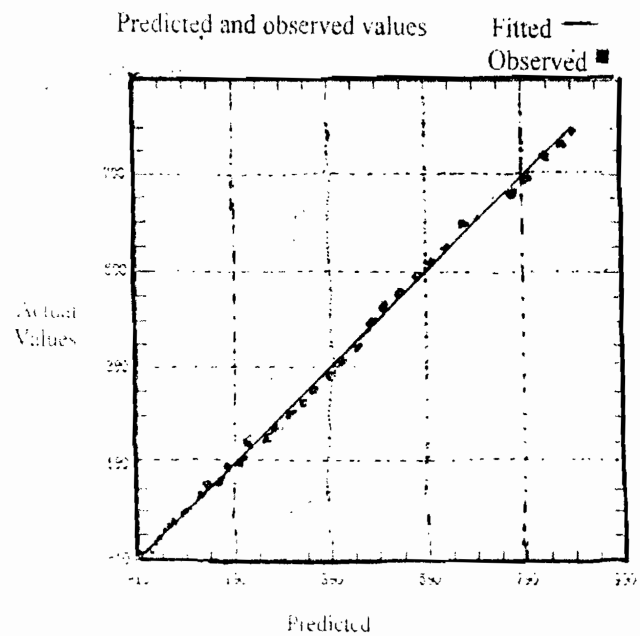

Fig. (1): Shows the actual values of weight Vs predicted values from equation No. (3).

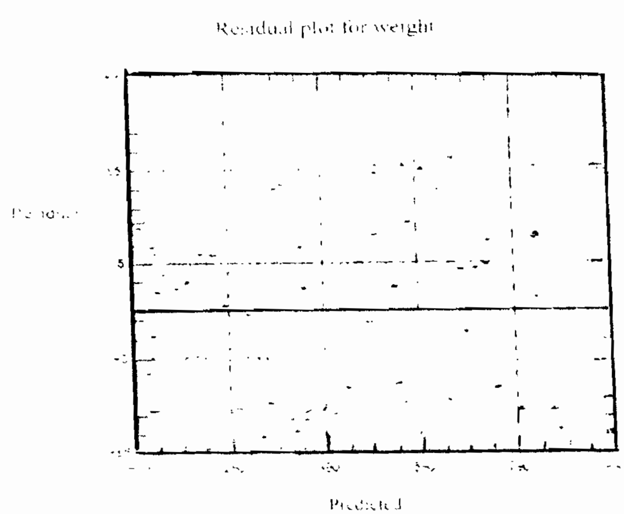

Fig. (2): Plot of residuals on predicted weight.

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إعداد جدول الوزن الطرى لأشجار ايوكالبتوس ***Eucalyptus camaldulensis* Dehn.** النامية فى مشاجر شمال العراق

سامى حميد مجيد

قسم الانتاج النباتى – المعهد التقنى الحويجة – العراق

نظراً لإزدياد الأهمية الاقتصادية لأخشاب ايوكالبتوس وخاصة فى مصانع الورق استهدفت الدراسة الحالية تحضير جدول الوزن الطرى بإتباع الطرق الإحصائية المعتمدة وباستخدام نظام Statgraph الاحصائى فى الحاسبة صفر ففى أيلول عام ٢٠٠١ تم جمع البيانات حول ارتفاع وأقطار لـ ١٢٣ شجرة من أشجار اليوكالبتوس *Eucalyptus camaldulensis* النامية فى مشجر غابات دبس فى شمال العراق وتسجيل أوزانها بعد الاسقاط ثم استخدمت هذه البيانات فى اشتقاق المعادلات الرياضية ، ولأجل التفاضل بين المعادلات المشتقة واختيار أدق معادلة معبرة لتحضير جدول الوزن استخدمت عدة مقاييس للدقة منها الخطأ القياسى المقدر ومعامل التجديد والاختبار غير المتحيز لعام صفر من ٢٢ معادلة خطية بسيطة و ٤ معادلات مشتقة بطريقة الانحدار المتدرج و ٦ معادلات غير خطية تم انتخاب المعادلة الآتية :

$$W = 6690.775 - 7791.0113 \log d + 1262.822 \sqrt{d} - 9058.146\ 1/\sqrt{d}$$

والتى أعطت أفضل مقاييس الدقة مقارنة مع جميع المعادلات المستنبطة حيث كان الخطأ القياسى ٨,٨٦٩ ومعامل التحديد ٠,٩٩٩٥ وبذلك تم تحضير الجدول الخاص بالعلاقة بين الوزن (W) والقطر (d) فقط كمتغير مستقل ونظراً لوجود عدة معادلات دقيقة فى هذه الدراسة يمكن الاستفادة منها فى تحضير جداول وزن أخرى باستعمال متغيرات مستقلة أخرى كالارتفاع أو القطر والارتفاع معاً صفر ٠