Juvenile Height Equations for Plantation-Grown Date Palm (*Phoenix Dactylifera* L.)

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***Abstract*: The juvenile height equation was developed forplantation-grown *Phoenix dactylifera L.* species in Modibbo Adama University of Technology (MAUTECH) Date Palm Plantation. In the four hectare date palm plantation, 15 sample plots of 35 x 35m wererandomly laid in the entire plantation.Ineach of the laid plot, all the standing trees were enumerated, and measurements were carried out on the variable of interest. The collected sampled plots data was divided into two groups for model calibration (70%) and model validation (30%). The measured tree height was fitted as a function of computed Crown Area (CA) and Number of Branch leaves, using stepwise regression method The predictive abilities of the selected juvenile height equation was evaluated, using Coefficient of determination (R^2), the bias (Ê) and Standard Error of Estimate (SEE). The results on degree of association between the juvenile tree height, crown area and number of branches revealed a strong positive correlation coefficient. The predicted height models were ranked and screened, and the best equations was chosen based on its high coefficient of determination (R^2) value of 75.8%, low SEE value of 0.2398. The result on the residual shows no significant difference between the observed and the predicted data (P> 0.05).which is an indication that the model is of good fit.The result of this study reveals that the height equation generated will serve as a reference to determine the future height equation of the Date palm (*Phoenix dactilyfera L.*) plantation in any area having similar environmental conditions.**

Keywords*: Juvenile, height equation, Plantation-grown, *Phoenix dactylifera

I. INTRODUCTION

Date palm (*Phoenix dactylifera L.*) is considered as one of the oldest and main staple and ancient crops in Southwest Asia and North Africa. Besides, dates can be grown in Australia, Mexico, South America, southern Africa, and the United States, especially in southern California, Arizona, and Texas (Chao and Krueger, 2007; Al-Harrasi *et al*., 2014; Hazzouri *et al*., 2015). Date palm (*Phoenix dactylifera* L.) is believed to have been introduced into Nigeria in the early 8th Century by Arab traders from North Africa. Date fruit called 'Dabino' in Hausa is a highly valued delicacy among many communities in Nigeria, particularly the northern part of the country. The fruits are especially used during ceremonies, festivals and during breaking of fast among the Muslim faithful.

Date palm *(Phoenix dactylifera* L.*)* is a tree which is extensively cultivated for its edible fruit. The growth habit of palms is a cylindrical, no branching stem, and relatively tall trunk. The trunk of date palm is composed of vascular bundles held together with connective tissue. Towards the periphery, where the leaf bases are embedded, the tissue tends to become more lignified and tough (Barreveld, 1993). The date palm tree commonly grows to a height of about 10 to 15m and features a slender trunk of more or less constant diameter from the base to the crown. Each year the old leaves are cut off at the base of the leaf stem. If the bases of the leaves are cut off, the trunk becomes smooth, much smaller in diameter, and more difficult to climb (Al-Suhaibani *et al*., 1988). Date palm lengthwise growth is upward and is provided by means of leaf growth from apical meristem and is a function of fertilization, irrigation, pruning and so on. Overall length of date palm depends on variety and region, and in some cases as Shahani variety in Jahrom becomes 20 meters and more (Hashempour, 1999).

Growth model, it simply means those basic tools for mathematical modelling of the sigmoid growth of tree characteristics are relatively simple non-linear equations, generally referred to as growth functions (Van Laar, Akca 2007; Pretzsch 2009). The growth model imitate the real growth of trees and forest stands, smooth cyclic fluctuations and filter random noise accompanying empirical growth measurements (Zeide 1993). In this way, they provide better knowledge of causes and mechanisms of growth and allow predicting the values and increments of modelled variables. They also facilitate the quantification of assumed growth responses or estimation of the maturity degree of an organism (Fitzburgh 1976; Vanclay, 1994).

Modelling is especially important for species of widespread commercial use, both to understand growth and development of the species and to make better management decisions aimed at increasing productivity (Fernandez and Norero, 2006). Moreover, accurate growth and yield predictions of trees and forests are important requirements for facilitating sustainable management of forest resources.

In forest growth modelling, it is common to find both construction of new mathematical equations (Boisvenue *et al*., 2004; Fontes *et al*., 2003; Wang *et al*., 2005) as growth models or development of existing mathematical equations further to achieve more realistic predictions. Among the already available mathematical functions which have been used to develop growth or yield models in the past, Bertalanffy (1957), Lundqvist-Korf (1939) and Schumacher

(1939) functions are most common (Adame *et al*., 2008; Palahi *et al*., 2004; Rammig *et al*., 2007; Salas and Garcia, 2006; Sanchez-Gonzales *et al*., 2005). The new models were mostly constructed by using assumptions on the relationships between response variable and candidate explanatory variables. In latter stages, those relationships were mathematically tested to obtain the statistical parameters which determine the magnitude and the direction of the relationships.

In commercial forestry, the important management decisions on different activities such as fertilizing, thinning and harvesting are taken long before the trees achieve the required end dimensions. Tree height is therefore commonly considered as the first input parameter to predict the important tree growth variables such as diameter, volume, crown size etc. It is therefore important to be able to make predictions of required tree variables from height, so that the change of growth with time can be readily determined. Hence; looking to the important of growth modelling in forestry, it assist forest researchers and managers to generate formula which provide an efficient way to prepare resource forecasts, formulate prescription, and guide forest policy decision into dynamics. Therefore, the present study will be carried out to develop height growth equation for *Phoenix dactylifera L.* in MAUTECH Date palm plantation of Adamawa state.

Information on site quality and growth of *Phoenix dactylifera* in Yola is scarce. This incomplete knowledge can dissuade potential investors from planting trees and frustrate efforts to develop sound management plans. Because species that are grown outside their native range typically exhibit growth and developmental patterns that differ significantly

from those of the species within its native environment, it is also risky to extrapolate growth predictions to new geographic areas (Zobel *et al*., 1987).

Over the years the growth and production of date palm takes many years before bearing fruit as a result of it's long life cycles and long period of juvenility. Numerous studies have been carried out on date palm, but little or non-studies were carried out on juvenile's height growth equation of Date palm in Adamawa State. Date palm is known to have a long life cycle and long period of juvenility. In other to efficiently predict the height growth rate of Date palm (*Phoenix dactylifera L.*), understanding the growth pattern, most especially, height growth is very essential, due to the harsh weather and limited amount of rainfall per annum in the state. Thus, this research seeks to develop the juvenile height growth equation which will provide useful information in determining tree height in relation to the crown diameter and leave branches.

II. MATERIALS AND METHODS

Study area

The study was carried out in the Date palm (*Phoenix dactylifera L.)* Plantation located in Modibbo Adama University of Technology Yola, Adamawa State which is situated between latitude $9^0$20' 00" and $9^0$21'30" N and longitude $12^0$29'00"E and $12^0$30, 30"E (Figure 1).

Modibbo Adama University of Technology Yola is in Girei local government area of Adamawa state which falls under Sudan savannah type of vegetation. The local government has a population of 129,855 people (NPC, 2006) and with total land mass of about 2186 km^2 (Adebayo, 1999). The dominant tribe is the Fulbe or Fulani; however, a substantial number of Bwatiye also dwell in villages such as Greng, Ntado, and Labondo within the Girei local government area. The local government shares boundaries with Song local government in the north, Fufore local government in the east while River Basin acts as a physical boundary between the local government, Yola North and Yola south local government in the south and Demsa local government areas in the west (Adebayo and Tukur, 1999).

It has a tropical climate with distinct dry and wet season. The rainfall begins in April and ends in October while dry season commences in November and ends in March. It has a minimum average temperature of 20.5^0C and a maximum temperature of up to40^0C (Adebayo and Zemba, 2020).

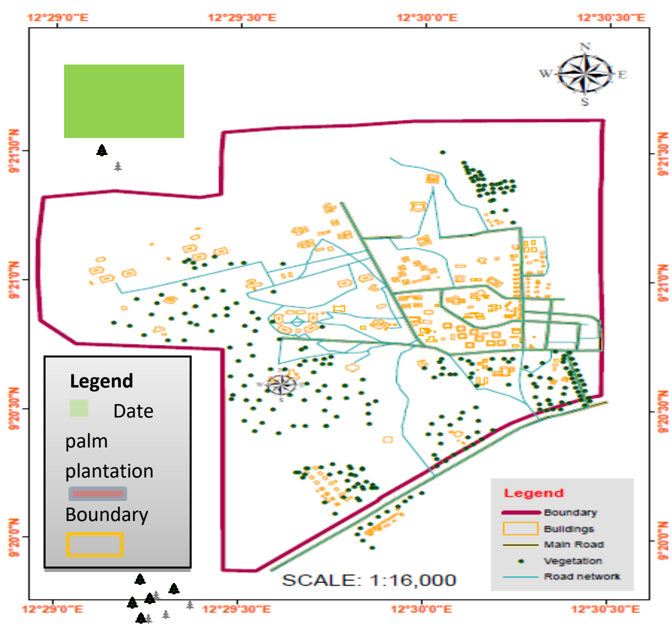

Figure 1: Map of Modibbo Adama University of Technology Yola, showing the study area.

(**Source:** GIS UNIT, Department of Geography, MAUTECH, 2015).

Data collection

In the entire four hectares of land of Date palm (*Phoenix dactylifera)* plantation fifteen (15) sample plots of 35 x 35m was laid, in which all the standing trees were enumerated, and measurements were carried out on the Total tree height of all the trees in the sample plot, Crown width and numbers of leave branches.

Estimation of tree variable

The Crown Width (CW) of the enumerated trees in the sampled plots was calculated as:

$$CW = \frac{(d_1+d_2)}{2} \quad \text{-------------} \quad (1)$$

while, Crown Area (CA) was estimated as:

$$CA = \frac{\pi(cw)^2}{4} \quad \text{-------------} \quad (2)$$

Where,

d_1= distance 1of the crown size.

d_2=distance 2 of the crown size.

π = Constant

Model formulation and Validation

The sampled plots data was split into two sets, Majority (70%) of the collected data was used for model development, while the remaining 30% was reserved for model validation (Moore *et al*. 1996).

Model Comparison and Selection

Selected model was evaluated quantitatively by examining the magnitude and distribution of residuals to detect any obvious patterns and systematic discrepancies and by testing for bias and precision to determine the accuracy of model predictions (Vanclay, 1994; Soares et al., 1995; Mabvurira and Miina, 2002). On the other hands, after parameter estimates were obtained, the predictive abilities of the selected juvenile height functions were evaluated, usingCoefficient of determination (R^2), Bias ($\hat{E}$) and Standard Error of Estimate (SEE).

$$R^2 = 1 - \frac{\sum_{i=1}^{m}\sum_{j=1}^{n}(H_{ij} - \hat{H}_{ij})^2}{\sum_{i=1}^{m}\sum_{j=1}^{n}(H_{ij} - \bar{H}_{ij})^2} \quad \text{------------} \quad (3)$$

$$\hat{E} = \frac{\sum_{i=1}^{m}\sum_{j=1}^{n}(H_{ij} - \hat{H}_{ij})^2}{n} \quad \text{-------------} \quad (4)$$

$$SEE = \sqrt{\frac{SSE}{n-p}} \quad \text{-------------} (5)$$

Where,

R^2 = coefficient of determination.
E = Bias
SEE = Standard Error of Estimate
H_{ij}=measured height
$\hat{H}_{ij}$= estimated values of tree heights
n_j = number of trees in the i^{th}plot
m_i=number of plots in the j^{th}
n= number of observations used to fit the model, and
p= number of model parameters.

III. RESULTS AND DISCUSSION

Characteristics of Sample trees of Date palm (Phoenix dactylifera L.)

A total number of 296 trees were enumerated in the 15sampled plots randomly laid in the study site. Statistic summary of the stand characteristics (number of trees, height, crown area and number of leave branches) are presented in Table 1. It was observed that the number of trees ranges between 15 to 23; the tree height ranges between 0.16 to 2.1 m, while, crown area and number of leave branches ranges between, 0.02 to 6.28 and 4 to 33 respectively.

Table 1 Statistics Summary of the Stand Characteristics

Tree Variables	Mean	Min	Max	Std
NTR	10	15	23	5.902
H(m)	0.823	0.169	2.071	0.455
CA (m^2)	1.277	0.022	6.275	1.813
NLB	12	4	33	5.124

NTR =Number of trees; H =Height; CA =Crown Area, NLB = Number of leaves branch

Correlation Analysis

Presented in Table 2 is the result of degree of association between the juvenile height, crown area and number of branch leaves of *Phoenix dactylifera*. It was revealed that there was a high convergence of the data at lower tree height for both crown area and number of branch leaves (Figure 2). This indicated that there was a strong positive relationship between the juvenile height and the crown area (0.831), while that of number of branch leaves is 0.816. The graphical representation of the relationship is depicted in figure 3 and 4 respectively.

Table 3: Correlation of Tree Height with Growth Variables

	Tree Height	Crown Area	No. of leaves Branch
Total Height	1		
Crown Area	83.1	1	
No. of Leaves branch	81.6	79.1	1

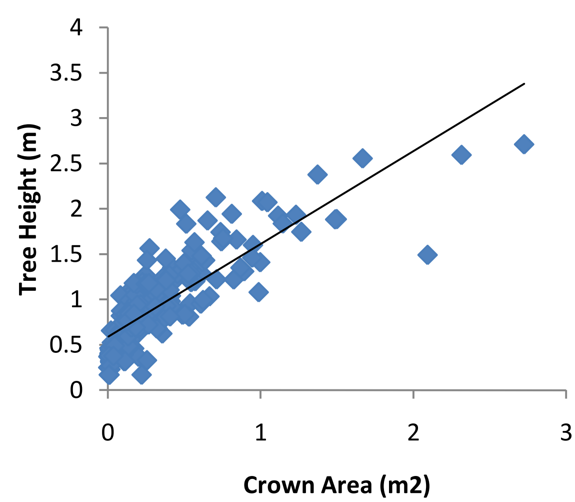

Figure 2: Showing correlation between Tree Height with Crown Area

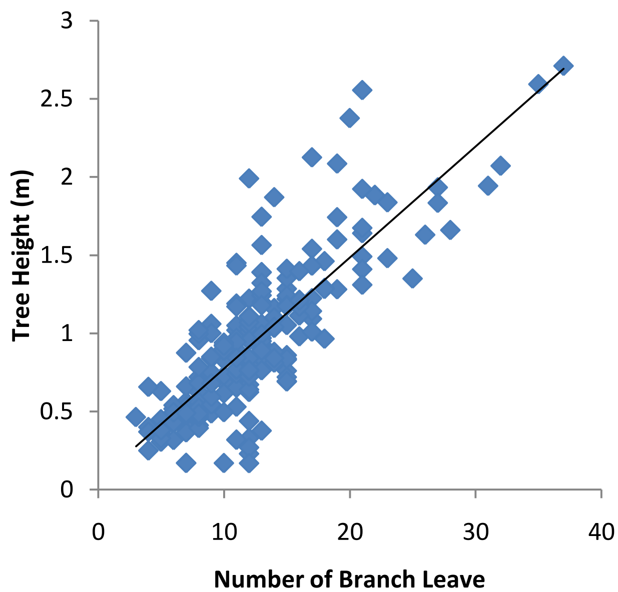

Figure 3. Correlation relationship between Tree height and Number of branch leaves

Regression Analysis Result

The result on the fitting models varies from model to model. The six predicted models (Appendix I) were ranked according to their high R^2 value. The model with highest R^2 value was selected as the best juvenile height equation for the studied species. The R^2 value, parameter estimate and standard error of estimate of the best two ranked models are presented in Table2. The best equation (Model II) is presented as:

$$H = 0.274 + 0.610CA + 0.037\ NBL \qquad (6)$$

Table 4 Parameter estimate and the fit statistics of the best two selected models

Model	Parameter estimates			R^2	SEE
	$\beta 0$	$\beta 1$	$\beta 2$		
I	0.588	1.025	-	69.1	0.2706
II	0.274	0.610	0.037	75.8	0.2398

Model Testing and Validation

According to Shugart (1984), model validation is a procedure, in which a model is tested on its agreement with a set of observations that are independent of those observations that was used to structure the model and estimate its parameters. Figure 4 show the graphical representation of the observed and the predicted juvenile tree height data. The result of the paired t-test of significance on the goodness of fit statistics showed that the computed t-value is less the critical t-value at 0.05 level of probability. This implies that there exists no significance difference between the observed and the predicted juvenile tree height. The lack of significance ($P > 0.05$) in the test was taken as evidence of acceptability of the prediction model. The residual (Table 4) exhibited a low value (0.009) difference between the predicted and observed data, indicating the goodness of fit of the predicted equation. Also, the low value (1.05 x10^{-6}) of the estimated bias (Table 4) indicates that the selected model can be used to predict juvenile tree in *Phoenix dactyfera* plantation without any correction on the predicted value.

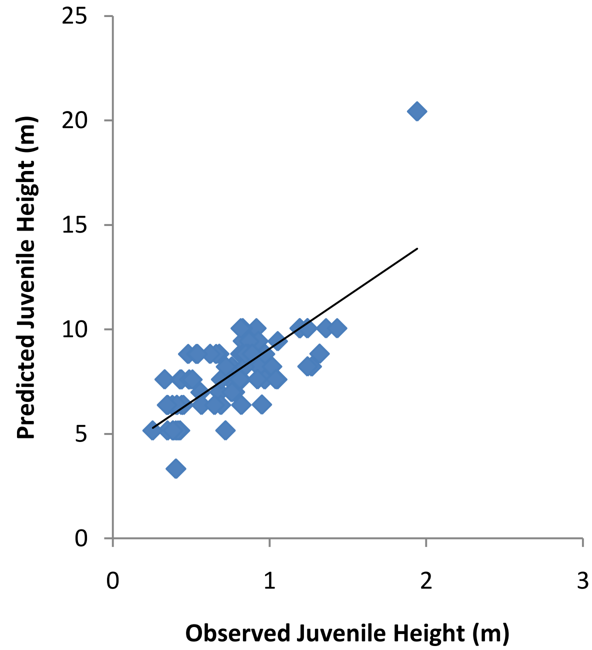

Figure 4: Graph showing the correlation between Observed Tree Height against Predicted Tree Height

Table 4: Validation model Result

Specie	No. of trees	Mean actual height(m)	Mean predicted height(m)	Mean Residual	Bias
Phoenix dactilyfer a L.	77	1.469	0.760039	0.009	1.05 x 10^{-6}

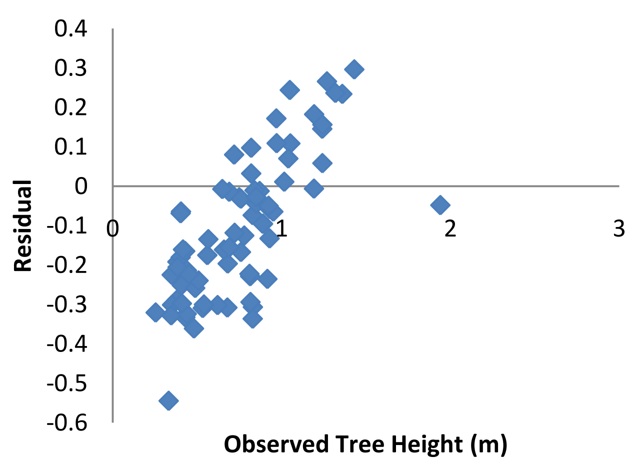

Figure 5: Graph showing relationship between the Residual and Observed Tree Height data

IV. CONCLUSION

Many researchers have used tree diameter and its modification for predicting the height of different tree species. Thisresearch have proved that a reasonable height equation can also be predicted from crown area and number of branch leaves as against the use of tree diameter by the previous authors. The predicted model may not be clearly statistical superior as predicting height as its species specific counterpart, but has a practical advantage and the result is promising enough to warrant further research.

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Appendix I: Predicted Juvenile Height Equation for *Phoenix dactyfera* L

Model	Parameters	Coefficients	R^2	t	Sig.	Ranking
	$\beta 0$	0.588	69.1			
I	$\beta 1$	1.025	(0.2706)	22.014	0.000	2
	$\beta 0$	0.274		5.986	0.000	
II	$\beta 1$	0.610	75.8	9.049	0.000	1
	$\beta 2$	0.037	(0.2398)	7.769	0.000	
	$\beta 0$	- 0.142		-0.521	0.603	
	$\beta 1$	0.021		3.545	0.000	
III	$\beta 2$	0.666		5.314	0.000	6
	$\beta 3$	0.127	75.8 (0.27186)	0.819	0.414	
	$\beta 4$	0.001		0.366	0.715	
	$\beta 5$	-0.094		-.918	0.360	
	$\beta 0$	-0.211		-1.094	0.275	
	$\beta 1$	0.021		3.557	0.000	
IV	$\beta 2$	0.627	75.8 (0.27131)	9.558	0.000	3
	$\beta 3$	0.163		1.351	0.178	
	$\beta 4$	-0.117		-1.438	0.152	
	$\beta 0$	0.015		0.160	0.873	
	$\beta 1$	0.023		4.314	0.000	
V	$\beta 2$	0.685	75.6 (0.27183)	13.774	0.000	5
	$\beta 3$	-0.008		-0.685	0.494	
	$\beta 0$	0.034	75.5 (0.27149)	0.366	0.714	
VI	$\beta 1$	0.022		4.458	0.000	4
	$\beta 2$	0.687		13.875	0.000	

Value in parenthesis = Standard Error of Estimate