ALLOMETRIC ESTIMATION OF THE BIOMASS OF *Musa* spp. IN HOMEGARDENS OF TABASCO, MEXICO†

[ESTIMACIÓN ALOMÉTRICA DE LA BIOMASA DE *Musa* spp. EN HUERTOS FAMILIARES DE TABASCO, MÉXICO]

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SUMMARY

Estimates of biomass in homegardens are primarily based on the tree component and few studies quantify the perennial herbaceous component. This component is of importance in the humid tropics of Mesoamerica, where distinct varieties and species of banana (*Musa* spp) are cultivated. This crop represents a dynamically stable biomass within homegardens and provides owners with continual production for alimentation and cash income. The aim of this study was to produce an allometric model for estimating the biomass of banana plants using dasonomic data, compare it to other models and estimate the biomass of cultivated banana plants from homegardens in the state of Tabasco, Mexico. This was based on the hypothesis that 1) the formulation of specific allometric models results in more precise estimations of the standing biomass of banana plants; and 2) banana plants contribute a significant proportion of the total biomass in homegardens. Dasonomic data and the dry weight of the above and below ground components of 30 individual plants of the most abundant species of banana (*Musa balbisiana* Colla) were collected in homegardens of the Los Rios region in Tabasco, Mexico. The mean biomass of the total plants of *M. balbisiana* harvested from homegardens was 5.85 kg plant^{-1}, with a range of 0.52 – 13.32 kg plant^{-1}. The above-ground and corm biomass represent 87.6% and 12.4% of total biomass respectively. The above-ground biomass (AGB) was strongly correlated with pseudostem diameter (DBH) and to a lesser degree with height data. The Husch and Schumacher – Hall models, with the variables pseudostem diameter at a height of 30cm (d_{30}), height of the pseudostem (HF) and total height (HT), performed best statistically; however, based on the crossed validation, the best model was that proposed by Kopezky, with the equation $AGB= -0.0927+0.0203*DBH^2$. In homegardens with banana plants, the banana biomass was between 0.1 and 1 t ha^{-1}, and in some cases between 2 and 5 t ha^{-1}. The mean density of the total biomass of the banana plants, in a sample of 69 homegardens where bananas were present, was 688 kg ha^{-1}, corresponding to 2% of above-ground biomass in the homegardens of the region of study.

Keywords: Allometric equations; above-ground biomass; *Musa balbisiana*; carbon; homegardens; Kopezky.

RESUMEN

Las estimaciones de biomasa en huertos familiares se basan principalmente en el componente arbóreo y pocos estudios cuantifican el componente herbáceo perenne. Este componente es importante en los trópicos húmedos de Mesoamérica, donde se cultivan distintas variedades y especies de plátano (*Musa* spp). Este cultivo representa una biomasa dinámicamente estable dentro de huertos familiares y proporciona a los propietarios una producción continua de alimentos e ingresos en efectivo. El objetivo de este estudio fue producir un modelo alométrico para estimar la biomasa de plantas de plátano utilizando datos dasonómicos, compararlo con otros modelos y estimar la biomasa de plantas de plátano cultivadas en los huertos familiares en el estado de Tabasco, México. Esto se basó en la hipótesis de que 1) la formulación de modelos específicos da como resultado estimaciones más precisas de la biomasa en pie de las plantas de banana; y 2) las plantas de banana contribuyen a una proporción significativa de la biomasa total en los huertos. Fueron recolectados los datos dasonómicos y el peso seco de los componentes por

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encima y por debajo del suelo de 30 plantas individuales de la especie más abundante de plátano (*Musa balbisiana* Colla) en los huertos familiares de la región de Los Ríos en Tabasco, México. La biomasa promedio del total de plantas cosechadas en los huertos familiares fue de 5.85 kg planta^{-1}, con un rango de 0.52 – 13.32 kg planta^{-1}. La biomasa sobre el suelo y el cormo representan el 87.6% y el 12.4% de la biomasa total respectivamente. La biomasa aérea estaba fuertemente correlacionada con el diámetro del tallo (DBH), y en menor medida con la altura. Los modelos de Husch y Schumacher – Hall con las variables diámetro a 30 cm (d_{30}), altura de tallo (HF) y altura total (HT) tuvieron los mejores rendimientos estadísticos, sin embargo, con base en la validación cruzada el mejor modelo fue el propuesto por Kopezky, con la ecuación AGB = -0.0927 + 0.0203 * DBH^2, donde AGB es la biomasa aérea y el DBH es el diámetro a la altura del pecho. En los huertos con plátano, la biomasa de plátano era entre 0.1 y 1 t ha^{-1}, y en algunos casos entre 2 y 5 t ha^{-1}. La densidad media de la biomasa total de las plantas de plátano, en una muestra de 69 huertos familiares donde había plátanos, fue de 688 kg ha^{-1}, correspondiente al 2% de la biomasa aérea en los huertos familiares de la región de estudio.
Palabras clave: Ecuaciones alométricas; biomasa aérea; *Musa balbisiana*; carbono; huertos; Kopezky.

INTRODUCTION

Homegardens represent the most diverse and frequent agroforestry system in the tropics (Saha *et al.*, 2009). They widely contribute to food production as well as providing ecosystemic services, particularly climate change mitigation by storing carbon in their biomass (De Beenhouwer *et al.*, 2016), and agrobiodiversity conservation (Kumar, 2006a). Above-ground tree biomass in homegardens varies considerably; in the humid tropics Roshetko *et al.* (2002) estimate it to be between 20 and 122 Mg C ha^{-1} in Indonesia; (Kumar and Nair, 2011), between 16 and 36 Mg C ha^{-1} in India; and Mattsson *et al.*(2013) between 48 and y 145 Mg C ha^{-1} in Sri Lanka. Generally, biomass in homegardens is similar to that reported for secondary forests (Roshetko *et al.*, 2002).

The majority of homegarden biomass is found in the tree and shrub components (Roshetko *et al.*, 2002). A share of homegarden biomass that has hardly been quantified is contained in the herbaceous-perennial component that includes species of the *Musa* genus L., 1753. Plants of this genus develop from a rhizome or bulb from which originates a pseudostem, providing a small tree like stem (FAO - INADES, 1977). Biomass is dynamically stable throughout the year by renewing the pseudostems that have already given fruit. Bananas are a source of income and food for millions of rural and urban households in the tropics (Calberto *et al.*2015). They are an important part of the daily family diet, particularly in regions with a long tradition of producing bananas such as in Central America -on the Atlantic coastal plains of Guatemala, Honduras, Nicaragua and in southeast Mexico, in the state of Tabasco (Calberto *et al.*, 2015).

The biomass in forestry and agroforestry systems is commonly estimated by allometric equations (Ketterings *et al.*, 2001; Chave *et al.*, 2005). These regression equations are derived from dasometric data and occasionally from the timber density of tree species (Brown, 1997; Kumar, 2006b; Roshetko *et al.*, 2002). Although these equations are not the most adequate for herbaceous perennial plants, they are still employed, in some cases accompanied by an empirical adjustment. For example, Roshetko *et al.* (2002) implemented an allometric equation proposed by Brown (1997) to 50% of the value obtained for banana biomass, thereby compensating for errors in the estimation of biomass due to a lack of calibration in the equations (Ketterings *et al.*, 2001).

Several authors (van Noordwijk *et al.*, 2002; Yamaguchi and Araki, 2004; Schmitt-Harsh *et al.*, 2012) make reference to an equation used for banana plants in Asia, based on the thesis by Arifin; cited by Hairiah *et al.* (2001): $AGB = 0.0303 DBH^{2.1345}$ (*AGB*: biomass (kg plant^{-1}); *DBH*: normal diameter of the pseudostem, in cm, at 1.3 m). However, the work on which this equation is based has not been widely published, thus access to this applied method is difficult. As far as we know, allometric equations have not been developed in the Americas for regionally important species such as *M. balbisiana* (Rojas-García *et al.*, 2015).

Whereas equations for other species of the Musaceae family have been developed, these are not applicable to banana plants due to morphological differences:

Musa textilis Nee $AGB = \frac{5.1164}{1+1343.02e^{-0.1550Db}}$

Where: (*Db:* base diameter in cm taken 5cm above ground level);

Ensete ventricosum (Welw.) Cheesman (Negash *et al.*, 2012):

$$AGB = -6.57 + 2.316\, ln(DBH) + 0.124\, ln(TH)$$

Where: (*TH*: total height in m).

This paper presents and compares allometric models that use dasonomic data to calculate the biomass of *M. balbisiana*; subsequently the best equation for estimating the biomass of banana plants (*Musa* spp.)

is applied to homegardens from the tropical lowlands of Tabasco, Mexico.

MATERIALS AND METHODS

Study area

The study was carried out in the Los Ríos region, in the lower drainage basin of the Usumacinta River, in Tabasco, Mexico. Annual precipitation is 2,550 mm and the mean annual temperature is 27.3 °C (SMN, 2015). The sampling sites correspond to the communities of Pochote and Jobal, in the municipality of Emiliano Zapata (17°42’18”N - 91°40’33”W); Ramonal and Capulín, in the municipality of Balancán (17°48´17”N - 91°18’42”W); Corregidora and Niños Héroes in Tenosique de Pino Suarez (17° 25´35”N - 91°17’37”W).

Sampling of *M. balbisiana* biomass

Using high-resolution satellite images, we selected home gardens in the communities. We numbered home gardens in each comunitie and then used random numbers to select them. If the owners of a selected home garden were absent or denied permission, we proceeded to the neighbouring one. We used a GPS to record the coordinates of the vertices in each home garden and calculated its surface area using ArcView GIS 3.2. A database of species present in a sample of 108 homegardens in the study region was used to select the most abundant species of banana, *M. balbisiana* (Alcudia-Aguilar *et al.*, 2017). In a sub-sample of 108 homegardens, 30 banana plants with a diameter at breast height (DBH) of over 2,5cm were harvested. Three diametric classes were selected ensuring that all of the categories were represented. Only plants that had not yet had their fruit or leaves harvested were selected. Banana plant diameter was determined by measuring the circumference of the pseudostem with a measuring tape at a height of 10cm (basal diameter, d_{10}), 30cm (stump diameter d_{30}), 130cm (DBH d_{130}) and at trunk height (200cm) (Segura and Andrade, 2008). The height of the pseudostem (HP) and total height (HT) was determined with the aid of a Suunto clinometer and crown height (HC) was calculated by subtracting HP from HT. Total height was considered as the distance from the ground to the apex of the last emerged leaf (Negash *et al.*, 2012).

After measurement, the plants were uprooted and separated into the following components: pseudostem, foliage, corm, and raceme. The pseudostem (“trunk of the plant”) consists of concentrically arranged leaf vines; the foliage component is composed of the petiole, mid-veins, leaf lamina; the corm component consists of adventitious roots, and the raceme comprises the peduncle, fruit and flowers (FAO - INADES, 1977). The fresh weight of each component was determined at each sampling site, using a precision spring balance ($\pm$ 0.1 kg). Dry weight was determined by taking a 5cm thick disc from the lower, middle and upper parts of the pseudostem; the corm was divided into thirds corresponding to the upper, middle and lower parts. A sample was taken from each third from each component of the plant (Negash et al., 2012). The foliage component was cut into small pieces; these were mixed, and a 1.2 kg sample was taken in order to ascertain the dry weight. The weight of the raceme included the fruit (sample of 1.2 kg), the peduncle and the flowers (complete samples). The fresh weight of the samples was determined before being placed in plastic bags for transport to the Laboratory of Plant Ecophysiology and Agroforestry Systems (LPEAS) at the El Colegio de la Frontera Sur Research Centre – Villahermosa Campus, Tabasco, Mexico. In the laboratory, the samples were cut in half, dried in the air for 2 weeks and then oven dried at 70°C until attaining constant weight (Acosta *et al.*, 2002). The fresh/dry weight relationships were calculated for each sample to convert the fresh weight total of each component of the biomass recorded in the field into dry weight (Negash *et al.*, 2012).

Formulation of the biomass models

The allometric models of the biomass were determined for each separate component of the biomass (corm, pseudostem, foliage and raceme), above-ground biomass (pseudostem, foliage and raceme) and total biomass (sum of the four components) using lineal and non-lineal regression equations (Segura and Andrade, 2008). The most important variables in determining the variations in biomass were identified by means of a regression analysis. The SAS software was used to adjust the parameters of the equations. Eight generic allometric equations proposed by Segura and Andrade (2008) for estimating tree biomass were tested. The Spurr, Stoate, Meyer and Schumacher–Hall models were duplicated with the variables of stem height (SH) and total height (*TH*) to determine which of this best explain biomass variation. The best fit model for the data, based on the adjusted determination coefficient (R^2-ajust.), the determination coefficient (R^2) and the lowest mean squared error (MSE) (Segura and Andrade, 2008), was selected.

Validation of model

To validate the models, the model fits were applied to five groups of data, using 80% of the data randomly selected from the total group of 30 plants; the remaining 20% was used to independently measure goodness-of-fit. To compare the goodness-of-fit among the models, the mean model error (MME), mean absolute difference (MAD), model efficiency (ME) and the determination coefficient (R^2) (Daren and Smith, 2007) were determined by the following: 1) MME=$\sum(y_i - \hat{y}_i)/n$, 2) MME(%)=100χ (MME/ $\bar{y}$), 3) MAD=$\sum|(y_i - \hat{y}_i)|/n$, 4)MAD(%)=100χ(MAD/$\hat{y}$), y_i = observed or real value; $\hat{y}_i$ = model estimated value; n = number of observations in model validation; y $\bar{y}_i$ = mean value of observed or real values. 5) ME=1-$(\sum(y_i - \hat{y}_i)^2)/(\sum(y_i - \bar{y}_i)^2)$, where y_i is the observed or real value; $\hat{y}_i$ = model estimated value; y $\bar{y}_i$ = mean value of observed or real values. In order to select the best model, a score was assigned to the values of MME, MAD and ME, where the highest value of ME and the lowest values of MME (%) and MAD (%) received the best scores (1, on a scale of 1 to 12). The model that achieved the lowest sum of the scores was considered as the best model.

Estimation of banana plant biomass in homegardens of Tabasco, Mexico

The biomass was estimated by calculating the surface area occupied by banana plants (*Musa* spp.) together with the dasonomic data collected from a random sample of 108 homegardens in Los Ríos region of Tabasco, Mexico (Alcudia-Aguilar *et al.*, 2017). Biomass was estimated using the equation of Cairns *et al.* (2003) and Chave *et al.* (2005), frequently used in the tropics, the equation of Arifin (Hairiah *et al.*, 2001) for bananas and the equation for *M. balbisiana* generated in this study and based on the Kopezky model (Segura and Andrade, 2008). For the equation of Chave (Chave *et al*., 2005), the apparent density of the pseudostem-dry biomass/fresh volume (expressed in g cm^{-3}) was calculated – using data from 30 plants of *M. balbisiana* harvested in the homegardens. The use of species density allowed a more accurate estimation of the biomass of this species (Brown, 1997). The biomass calculated from each equation was compared and any significant differences among equations were determined. Spearman's correlation coefficients were used to identify the variables from each plant component (pseudostem, corm, foliage and raceme) that presented the strongest correlations with biomass. A one-tailed ANOVA and a post hoc Tukey test (HSD) were performed in order to determine the differences in above-ground biomass estimated by the general equations and the calculated equation for *M. balbisiana* in the homegardens. If the variables did not show a normal distribution, the non-parametric Kruskal-Wallis and Mann-Whitney tests and non-parametric Spearman and Kendall correlations with a 0.05 significance level were applied. The analysis was carried out using the SAS version 9.1 statistical package.

RESULTS

Variables of biomass prediction in *M. balbisiana*

The above-ground, underground and total biomass demonstrated high and significant correlations with the data on stem diameter at distinct heights. The mean above-ground, below-ground and total biomass were 5.13 kg, 0.72 kg and 5.85 kg per plant respectively.

Models of biomass estimation

The equations that relate the independent variables most frequently used for biomass estimations d_{130}, HP and HT, formulated from the data provided by 30 plants of *M. balbisiana*, demonstrated a good fit., with six models presenting good performance (Table 1). The Husch, Schumacher – Hall – HT and Schumacher – Hall – HF logarithmic models showed a high coefficient of determination (R^2 = 0.95 and 96), in contrast with the Kopezky, Hohenadl – Krenn and Stoate models

Table 1. Prediction equations between the measured biomass and the estimated biomass for *M. balbisiana*.

Model	Equation	Statistical performance			
		R^2	MSE	PRESS	CV
Husch	$AGB=e^a \cdot DBH^2$	0.95	1.6	867.41	25.62
Kopezky	$AGB=a+b \cdot DBH^2$	0.88	1.9	316.74	27.89
Hohenadl-Krenn	$AGB=a+b \cdot DBH+c \cdot DBH^2$	0.88	1.7	138.89	26.52
Stoate	$AGB=a+b \cdot DBH^2+c \cdot DBH^2 \cdot HT+d \cdot HT$	0.89	1.7	279.46	26.55
Schumacher - Hall-HT	$AGB=e^a \cdot DBH^b \cdot HT^c$	0.96	1.6	867.49	25.60
Schumacher - Hall-HF	$AGB=e^a \cdot DBH^b \cdot HF^c$	0.96	1.5	869.58	24.87

MSE – Mean standard error; PRESS – predictor of the sum of the squares; CV – coefficient of variation. AGB: above-ground biomass (kg $plant^{-1}$); DBH: diameter at breast height (cm); HT: total height (m); HF: stem height (m); *a, a, b, c, and d: function fitting parameters*.

The MSE varied between 1.7 and 1.9 for the three models and the PRESS (predictor of sum of squares) varied from 138.89 to 316.74. The CV demonstrated a lower degree of variability in the observed data (Table 1). The Husch, Hohenadl – Krenn and Kopezky regression models that demonstrated the best fit and included the variable d_{130} were compared. In practice, this variable is the most used. The lineal regression analysis showed that the Husch model best fitted the d_{130} variable with the measured biomass, with R^2 = 0.95. The Hohenadl – Krenn model resulted in biomass values that were lower than the measured values, and to a lower degree, explains the variability in the biomass data (R^2= 0.88). On the other hand, the Kopezky model fits similarly to the Husch model R^2= 0.88) (Fig. 1).

Validation of allometric equations

The Hohenadl–Krenn model resulted in the best ME, followed by the Berkhout, Kopezky, Husch and Schumacher–Hall-HF models. The Stoate - HF, Kopezky and Berkhout models produced the best MME values, while the Hohenadl-Krenn, Kopezky and Husch models the best MAD values (Table 2). Considering the three criteria, the best model is that proposed by Kopezky. It has a high coefficient of determination (R^2 = 0.88), although the ME was less than in the Hohenadl–Krenn models. The MME was lowest in the Stoate – HF model, followed by the Kopezky model, and the MAD produced similar values in the Hohenadl–Krenn, Kopezky and Husch models (Table 2).

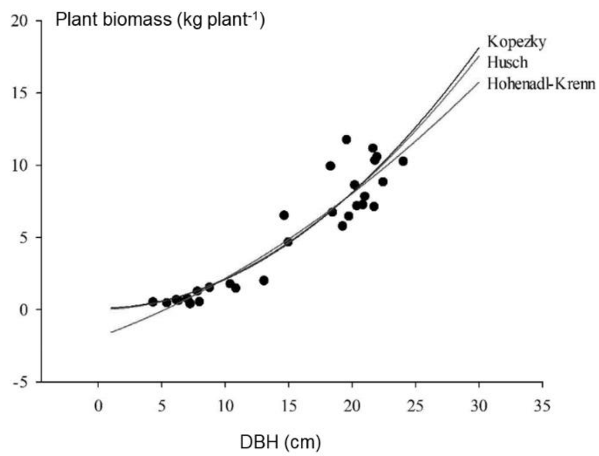

Fig 1. Lineal regression between the diameter at breast height (DBH) and the above-ground biomass regarding three best fit models.

Table 2. Model efficiency (ME), mean model error (MME) and mean absolute difference (MAD) values and scores for the allometric models

Models	ME		MME (%)		MAD (%)		
	Value	Score	Value	Score	Value	Score.	Score. Total
Berkhout	0.84	2	0.18	3	22.19	7	12
Kopezky	0.84	2	0.17	2	19.77	2	6
Hohenadl – Krenn	0.87	1	2.53	10	18.19	1	12
Husch	0.84	2	1.40	8	20.26	3	13
Spurr	0.80	5	0.30	4	23.33	11	20
Spurr-HF	0.82	4	0.18	3	22.32	8	15
Stoate	0.82	4	0.59	5	22.46	9	18
Stoate-HF	0.83	3	0.03	1	21.62	6	10
Meyer	0.82	4	0.62	6	22.51	10	20
Meyer-HF	0.61	6	17.00	11	31.11	12	29
Schumacher - Hall-HT	0.83	3	2.25	9	21.52	5	17
Schumacher - Hall-HF	0.84	2	1.06	7	20.31	4	13

The best parameters of fit from the models are observed in table 1; the equation according to Kopezky was: AGB= $-0.0927+0.0203*DBH^2$. This model will be implemented for the calculation of individual biomass of plants of *M. balbisiana* in the sample of 108 homegardens.

Biomass of homegardenss in Tabasco, Mexico

Banana plants are present in 65% of the sampled homegardens (n=108). In homegardens with banana plants, the mean biomass calculated with the equation generated based on the Kopezky model- was 688 kg ha-1. This represents 2% of the above-ground biomass in the homegardens. In the majority of homegardens with banana plants, the banana biomass was between 0.1 and 1 ton per hectare (Fig. 2a).

The generated equation showed significant differences in the mean biomass per hectare when applying the Arifin equation and the general equations of the above-ground biomass: Cairns and Chave (Kruskal – Wallis P = 0.000). The calculated biomass was greater using the Cairns and Arifin equations compared with the Kopezky equation (Mann – Whitney, P = 0.000 and 0.002). No significant differences were found between the biomass calculated using the generated and the Chave equation (Mann – Whitney, P = 0.841). There were significant differences among the above-ground biomass calculated using the Cairns, Chave and Arifin equations (Mann – Whitney P = 0.000 and 0.000) as well as between the Chave and Arifin equations (Mann – Whitney P = 0.005). The total calculated biomass for the Kopezky, Cairns, Chave and Arifin models was 556.96, 6,508.64, 615.30 and 1,201.86 kg ha^{-1} respectively (Fig. 2b).

DISCUSSION

The total biomass of the plants and their components were strongly correlated with the diameter measurements, particularly d_{30}. The correlations with the height variables were inferior to those with the diameter variables. This coincides with the results of several authors who consider that the best predictors of biomass, in descending order, are diameter, specific density of the timber and total height (Chave *et al.* 2005; (Segura and Andrade, 2008). There is broad agreement on the difficulty of measuring the total or commercial height of tropical trees, and has contributed to DBH becoming the most important variable for allometric equations (Day, 1985). Our results corresponding to banana plants indicate that this also applies in the case of *Musa balbisiana*.

Below-ground biomass was correlated with diameter measurements and TH. This indicates that banana plants invest in increasing energetic reserves as soon as they start to develop. Plants carbohydrates are produced by photosynthesis and are used for growth and energy (Goldschmidt, 1999). The levels of carbohydrates are involved in the regulation metabolic events an plant development (Goldschmidt, 1999). Therefore, the accumulation of carbohydrates during growth is essential for plant survival (Kozlowski and Pallardy, 1997). They provide energy for the growth of plant species and ensure survival in periods of drought, floods and high and low temperatures (Kozlowski and Pallardy, 1997).This property can be of particular interest under conditions of resource insecurity in homegardens, particularly relating to competition for light with larger tree species.

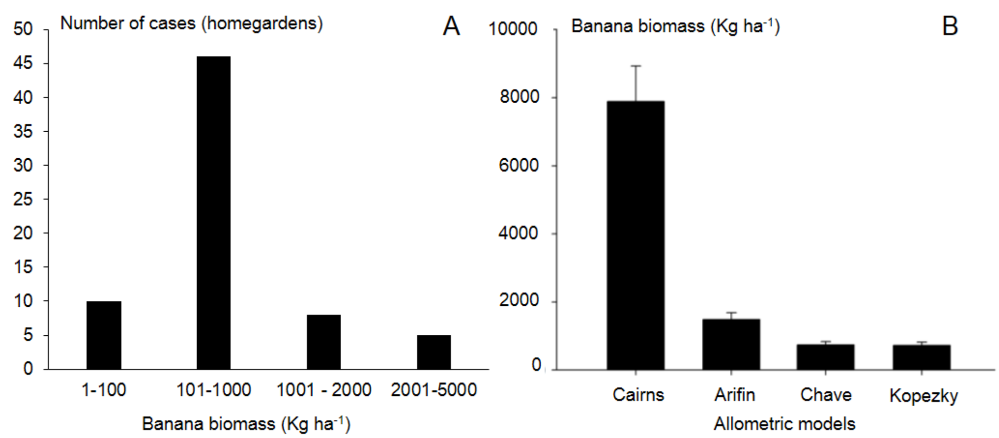

Fig. 2. A) Frequency of categories of banana plant biomass (*Musa* spp.) in 108 homegardens in the Los Rios region of Tabasco, Mexico. Biomass was calculated with the equation generated in this research. B) Mean biomass per hectare of the homegardens calculated using the model based on Kopezky and the Cairns, Chave and Arifin.

After *Ensete ventricosum*, a species of the Musaceae family that sustains a diverse agroforestry system in Ethiopia, banana plants develop the most dry weight per plant than any other herbaceous perennial (Tsegaye and Struik, 2000). Several authors have reported that the biomass of *E. ventricosum* and banana plants is affected by age, soil type, climate, altitude, transplanting and management practices (Nurfeta *et al*., 2008).

Espinoza-Domínguez *et al.* (2012) point out that regeneration from shoots has a strong impact on biomass and the mean total dry weight of 5.85 kg plant^{-1} obtained in this study confirms this since it is less than the value of 9.4 kg plant^{-1} reported by Negash *et al.* (2012) for *E. ventricosum.* This is probably because as many juvenile plants as those in the fructification stage were included in the sample. Thus, we can conclude that banana plants acquire considerable biomass that maintains them dynamically stable throughout the year. Our allometric equation generated from the Kopezky model is a valuable tool for estimating the biomass of banana plants. Both species of plants are herbaceous perennials and belong to the Musaceae family; they show similar growth and morphological characteristics to banana plants but as they display differences in the pseudostem, height and foliage, they are not adequate for measuring the biomass of banana plants.

The performance of the Kopezky model for measuring total biomass, using two constants and DBH, was better than in models which included one constant and the combination of DBH and height (Husch, Hohenandl – Krenn and Stoate). However, performance was lower when using one constant and total height or stem height in the Schumacher – Hall – HTc and Schumacher – Hall – HFc models. The Husch and Schumacher-Hall models were the best for calculating total biomass, using DBH, TH and SH. In the validation, in which 5 tests were considered, the Kopezky model scored higher than the two models that performed better statistically. The low values of MME (%) and MAD (%) were maintained in the five validation tests, resulting in the Kopezky model with two constants and DBH presenting the best predictors of total biomass.

The choice of the model has been made according to its predictive capacity. All models are widely used in allometric equations and volume tables, and all had a good fit. Regarding the biological significance of the models, the parameter "a" of the Kopezky equation allows to predict the biomass of the plants that reach 1.30 of height and whose DBH is 0. In this, it surpasses all the others. This is evident in Figure 1, where we see that a DBH = 0 corresponds to AGB = 0.0927, and where it is observed that for high values of DBH, the curves of Kopezky and Husch are better adjusted to the distribution of the point cloud, while the Hohenadl-Krenn curve underestimates the biomass.

There were no differences in the biomass calculated by the Kopezky and Chave equations. This is largely due to determining the density of *M. balbisiana*, resulting in a value of 0.08682 g cm^{-3}. By using this factor, the Chave model presented a good fit to the aforesaid values produced by the model generated in this research.

The biomass of the banana plants in the homegardens was not as high as expected, especially if we consider the mean of 55 tons of total above-ground biomass for the tree component in the study region. Our results signify that the biomass of the herbaceous perennial component is around 2% of the total biomass. However, it must be considered that this is an average value and that in approximately 8% of homegardens, herbaceous perennials contribute between 2 and 5 tons of biomass, equivalent to 5% of tree biomass.

CONCLUSIONS

The mean biomass of a total of 30 plants of *M. balbisiana*, harvested from homegardens of the lowlands of the state of Tabasco, Mexico, was 5.85 kg plant^{-1}, with a range of 0.52 – 13.32 kg plant^{-1}. The above and below-ground biomass represented 87.61% and 12.38% respectively. The above-ground biomass was strongly correlated with stem diameter and to a lesser degree with height data. The Husch and Schumacher – Hall models, with the variables d130, SH and TH, performed best statistically; however, based on the crossed validation, the Kopezky model produced the best results. The mean biomass of the herbaceous perennial component in the homegardens of Tabasco is equivalent to 2% of tree biomass.

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