ISSN:1991-8178

Australian Journal of Basic and Applied Sciences

Journal home page: www.ajbasweb.com

Morphometric Relations in Individual Plants of Elaeis Guineensis Jacq. in Southern Bahia, Brazil

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ARTICLE INFO

Article history:
Received 12 March 2015
Accepted 28 April 2015
Available online 5 May 2015

Keywords:
Height, diameter, growth, oil palm, plant-size relations

ABSTRACT

Background: Palm oil (*E. guineenses* Jacq.) is one of the main raw materials for the biodiesel and food industry in the world. In Brazil, the cultivation of this species has evolved in recent years, but basic information regarding this species growth is still scarce**. Objective:** This study analyzes the dendrometric and morphometric relations of 41 individuals selected in three stands located in the municipality of Taperoá, southern Bahia State, considering the whole range of age, and aiming to provide support to crop management. **Results:** The diameters growth curves of the plants had different behavior of those of their heights. Stabilization of the diameter growth curves takes place at around 20-25 years, whereas for height such tendency is not observed until the age of 36. The degree of slenderness ratio increases with age. The index of coverage and the proportion of canopy decline with age of the plants. Based on the diameter growth curve it would be possible to establish the age of 20-25 years as a reference for technical rotation of this species, and this reference needs to be based on fruit oil production data, which is the main objective of these stands. This reference needs to be based on fruit oil production data, which is the main objective of these stands**. Conclusion:** Judging the crown diameter, the current spacing utilized in such stands needs to be redefined, considering a maximum density of 113 plants/ha**.**

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To Cite This Article: Carlos Roberto Sanquetta, Dirceu Lúcio Carneiro de Miranda, Ana Paula Dalla Corte, Sylvio Péllico Netto, Mateus Niroh Inoue Sanquetta, Aurélio Lourenço Rodrigues, Guilherme Camacho Cadori., Morphometric Relations in Individual Plants of Elaeis Guineensis Jacq. in Southern Bahia, Brazil. ***Aust. J. Basic & Appl. Sci.,*** *9(11): 469-474, 2015*

INTRODUCTION

The Dendê tree or palm oil (*Elaeis guineennsis* Jcq.) is originally from the African continent, and its natural area of distribution comprises the entire Western African coast, from Senegal (parallel 16ºN) to Angola (Hartley, 1977; Wahid, 2005). It can also be found into the continent's interior, towards Congo, and in eastern Africa, including Madagascar Island (Moretzsohn *et al*., 2002). Palm oil has a good adaptation capacity and this characteristic has contributed to its dispersion around the world, integrating local flora as subspontaneous formations of palm oil stands, as well as in the form of commercial exploration.

In Brazil, palm oil tree was likely introduced by slaves in the 17th century, during the Atlantic slave trade (Savin, 1965). In that time, slaves mainly from Angola, Benin and Mozambique used to carry seeds with them inside the ships, which were possibly the starters of the first palm oil stands in the state of Bahia, more specifically on its coast (Chavez, 1984).

The palm oil fruit produces two types of oil: the palm oil, which are extracted from its mesocarp (external part of the fruit); and the nut oil, called palm kernel oil, which is extracted from the plant's seed. According to Pandolfo (1981), *apud* Cardoso (2010), it is possible to extract up to 22% of oil from the pulp and up to 3.5% of oil from the seed over the bunches weight. With a wide range of utilization, palm oil presents itself as raw material for alimentary, medicinal, oil-chemical and industrial usage.

Stands of palm oil have been emerging in world agriculture due its high production of oil per unit of area, reaching an average yeld of 4 to 5 tons of oil per hectare/year (Moura, 2008). The state of Pará is the greatest producer of palm oil, producing around 100 thousand tons per year, with 50 thousand hectares planted, corresponding to 93% of the Brazilian production (Harada, 2008; Furlan *et al*., 2006; Mapa, 2006; Lange, 2012). However, there is a concern regarding deforestation escalation in the Amazonian region, due the expansion of oil palm

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plantations for biofuel production, considering the extreme examples in the Asian continent (Butler, 2011). Lange (2012) mentions that four other Brazilian states (Amazonas, Amapá and Bahia) have areas of oil palm stands.

In the environmental and biological context, the most important aspects regarding palm oil plantings are related to plant, soil and climate (Brazilio *et al*., 2012). The plant's nutritional needs varies widely depending on yield required, genetic material used, planting spacing, plant age, type of soil and environmental factors (Santos, 2010). The most common planting density of palm oil is 143 plants per hectare, deployed as an equilateral triangle with 9 m of side, that is, a spacing of 7.8 m between rows and 9 m between plants in the same row (Berthaud *et al*., 2000).

Studies regarding the growth of palm oil are scarce. Particularly about the behavior of dendrometric variables and its morphometric relationships. There are no researches at an international neither at national level. This study has as objective the assessment of dendrometric and morphometric relationships of palm oil plants in southern Bahia state, considering the range of planting age. This paper has the purpose to serve as subsidy for palm oil management in Brazil.

MATERIAL AND METHODS

Study area:

This study was conducted in the county of Taperoá, lower southern region of Bahia state. Limited north by the county of Valença, on the south by Nilo Peçanha, east by Cairú and on the west by Teolândia county. The area central coordinates UTM X: 486.212 m Y: 8.504.380 m.

The climate is tropical and moist, with 24ºC average temperature. Rains are abundant and frequent from April to August and in the first three months of spring (September to November). Precipitation can reach up to 100 mm as monthly average. With respect to this characteristic, the county can be characterized as the rainiest in the state, with rainfall between 1,500 to 2,000 mm annually (Santos, 2010).

Study material and Methodological procedures:

In the study area, commercial stands were selected with the greatest possible range of ages, in other words, with ages varying from 3 to 36 years. A total of 41 plants were selected in three stands. It was kept a minimum distance of 100 m between sampled individuals, all of them located on the stands' borders. All the palms that were sampled presented regular phenotype and vitality, without any damages neither defects caused by natural nor pathologic factors.

In the field, the following dendrometric variables were measured, and they can be found in Figure 1:

Diameter at breast height (*DBH*) at 1.30 m above the ground level, measured in cm with a tape;

Plant diameter at 50 cm above the ground level (*d50*), measured in cm with a tape;

Canopy diameter (*dc*), measured in m with a tape with two orthogonal measurements;

Plant total height (*ht*), measured in m with a tape, after falling the tree;

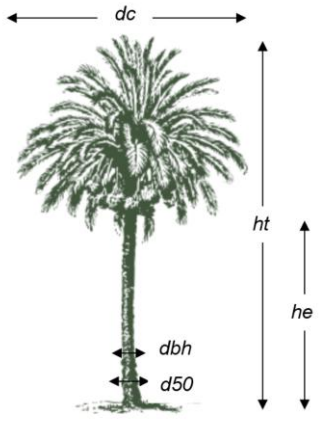

Fig. 1: Measured variables in the oil palm plants.

Where:

Stipe height (*hs*), measured in m with a tape, after falling the tree;

Canopy length (*l*), calculated by the diference between *ht* and *hs*;

Simple Pearson's linear correlations were analysed between the dendrometric variables and different ages.

The following attributes were calculated in order to assess morphometric relationships:

Degree of slenderness: expressed by the relation between height and plant diameter. In this paper, the variable *d50* was used instead of *DBH* (variable commonly used for this purpose) due the fact that the species has late height growth, not reaching 1.30 m of height in the first 5 years. This is related with the static stability of the plants (Durlo and Denardi, 1998).

$$DS = ht / d50 \quad (1)$$

Protrusion index: expressed by the relation between canopy diameter and the stem diameter (50 cm above the ground level). It can be used as an indicator of the required space for each tree, when a certain diameter is reached (Román *et al*., 2009).

$$PI = dc / d50 \quad (2)$$

Cover index: expressed by a relation between the plant's canopy diameter and total height. In case of correlation between the cover index and the trees' heights, this index can be utilized as an indicator for thinning throughout the stand's life (Durlo and Denardi, 1998).

$$CI = dc / ht \quad (3)$$

Canopy shape: expressed by the relationship between canopy diameter and canopy height. Considering one unique species and site, the lower the number, the higher is the tree productivity (Durlo and Denardi, 1998).

$$CS = dc / l \quad (4)$$

Canopy proportion: shows the percentage of the plant that is represented by the canopy. Along with canopy qualitative characteristics, it is an indicator of plant vitality. The higher the canopy percentage is, more vitality the plant has (Durlo and Denardi, 1998).

$$\%C = l / ht \quad (5)$$

Relationships between morphometric variables and the plants' ages were assessed later.

RESULTS AND DISCUSSION

Correlation between dendrometric variables:

All the tested linear correlations among the variables were significant at the level of 95% probability. Variables also presented an increase with age, however the correlations between ages and total and stipe heights were greater than the ones between diameters (*DBH*, *d50* and *dc*). Diameters and heights were positively correlated (Table 1).

Table 1: Correlation between dendrometric variables of *E. guineensis* in Southern Bahia.

	Idade	*dap*	*d50*	*dc*	*Ht*	*he*
Idade	1					
dap	0,7685	1				
d50	0,6177	0,8358	1			
dc	0,7837	0,8207	0,7139	1		
Ht	0,9387	0,8440	0,7248	0,8304	1	
He	0,9455	0,7589	0,6512	0,7427	0,9693	1

Despite of the seeming direct relationship between diameters and heights with ages, it is possible to notice that both diameter at 50 cm above ground level and canopy diameter raised with age, but it tended to stabilize around 20-25 years. On the other hand, heights (total and stipe) kept growing with age, not showing a trend of stability by the age of 36 (limit age recorded on the stands). This means that the set of points suggests that the asymptote has been reached for diameters but not for heights (Figure 2).

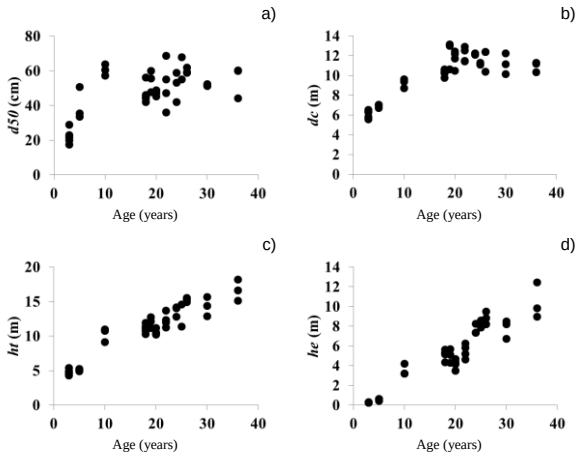

Fig. 2: Relations between dendrometric variables and age of *E. guineensis* in Southern Bahia (a: diameter at 50 cm aboveground; b: crown diameter; c: total height; d: stipe height).

The asymptotic value of the variable *d50* is around 50 cm, and for *dc* it is around 11 m. It is noticeable that there is a trend of canopy diameter reduction on more advanced ages, suggesting loss of green biomass and, possibly, the beginning of senility.

Based on the diameter growth curve , it would be possible to establish the age of 20 and 25 years as a reference for technical rotation. This reference needs to be validated in regard to fruit production data. It is important to know when the production of oil tends to stabilize or even decrease due the plant's senility. However, it is worth noting that nowadays the age of 25 years is used as the adequate time to reform old stands, considering that productivity decreases after this period and that harvesting fruits becomes unprofitable (Villela, 2009). Thus, the analysis of such dendrometric data aids the definition of this age as the adequate one for stand rotation.

Judging by the canopy diameter, the plantingspacing utilized should be redefined. The quincunx spacing is the one utilized nowadays, being consisted of plants spaced 7.8 m between rows and 9 m between plants in the same row (Berthaud *et al*., 2000). Based on this study's data, it could be defined a maximum planting density of 113 plants/ha, equivalent to 9.8 m between lines with 9 m between plants. This spacing do not considers the need of diversified spacing for possible consortium of plants in different systems, which is commonly done in Bahia and Pará.

Differently from what happens with wood species, this palm first reaches dimensional stability in diameter and after reaches maximum height. The maximum values of *ht* and *hs* reached in the limit age were 16 m and 10 m, respectively. The progressive increase in height after the stagnation of stem diameters growth is a factor that makes economical exploration of this species impossible. According to Villela (2009), excessive height growth makes this activity not profitable, therefore making the exploration not attractive. Moreover, palm oil trees have a gradual reduction of production after that age.

Morphometric relationships:

The degree of slenderness is lower than the ones for wood species, being the plant proportionally wider in diameter then high and slim. It is noticeable, however, that as age increases, growth in height and diameter becomes stable. Consequently, plants become proportionally higher, what results in a greater *DS* (Table 2)

Table 2: Morphometric relations by age of *E. guineensis* in Southern Bahia.

Age (years)	Index	*DS*	*PI*	*CI*	*L*	*CS*	*%C*
<10	$\overline{X}$	0,1876	0,2442	1,3163	4,5088	1,4305	92,1932
	s	0,0580	0,0647	0,0893	0,0354	0,1303	2,0744
	n	8					
10 a 20	$\overline{X}$	0,2160	0,2046	0,9485	6,4464	1,6479	58,1167
	s	0,0367	0,0358	0,0765	0,7631	0,2028	6,3273
	n	11					
20 a 30	$\overline{X}$	0,2432	0,2281	0,9444	6,2369	1,9412	49,7007
	s	0,0399	0,0408	0,1372	0,8772	0,3534	9,7338
	n	16					
>30	$\overline{X}$	0,2952	0,2106	0,7224	6,3633	1,7435	41,6051
	s	0,0607	0,0310	0,0879	0,5148	0,1162	5,6218
	n	6					

According to what was observed later, the increase on the degree of slenderness is a harmful factor for economical use. Plants excessively high make the harvest of fruits difficult. Because of this, genetic breeding, besides being directed to increasing oil productivity, should consider this species management.

The index of slenderness do not presents a growing trend neither a reducing trend as age increases, keeping itself stable. This means that the relation between canopy diameter and stem diameter do not decrease over time. On the other side, cover index behaves differently, reducing with age and indicating that as the plants grow older, their height growth becomes greater than canopy diameter growth, as it was previously related. In turn, canopy length (*l*) is lower for plants less than 10 years old, and they start to stabilize after this age. The same happens with canopy shape. This is due *dc* stabilization over time.

For the canopy portion, it becomes evident an inverse linear relationship. This means that as plants grow older, the proportion of canopy starts to decrease. During the younger ages, palms have more than 90% represented by their canopies, but as they become older, this value is reduced to approximately 40%. This is due the constant stem grow and to the stabilization of canopy dimensions (Figure 3).

Literature do not reports morphometric relationships studies for *E. guineenses*. In Brazil, only studies with wood species were done by Durlo and Denardi (1998), Durlo (2001), Román *et al*. (2009) and Wink *et al*. (2012).

Studies done by Tonini and Arco Verde (2005), with wood forestry species native from Amazon, showed that the canopy of *Bertholletia excelsa* Bonpl. is around 50 times greater than its *DBH*.

According to these authors, other species, such as: *Carapa guianensis* Aubl., *Tabebuia avellanedae* Lorentz ex Griseb., and *Hymenaea courbaril* L., have canopies 14.7; 32.2; 33.1 times greater than their *DBH*, respectively. These authors have observed that canopy diameter and length grow as *DBH* and height grow, except for *Carapa guianensis*.

Researches developed by Orellana and Koehler (2008) regarding canopy proportion of *Ocotea odorifera* in Araucaria Forests in Paraná, showed that the maximum canopy average proportion value was 77.8% and that the minimum value found was 30%.

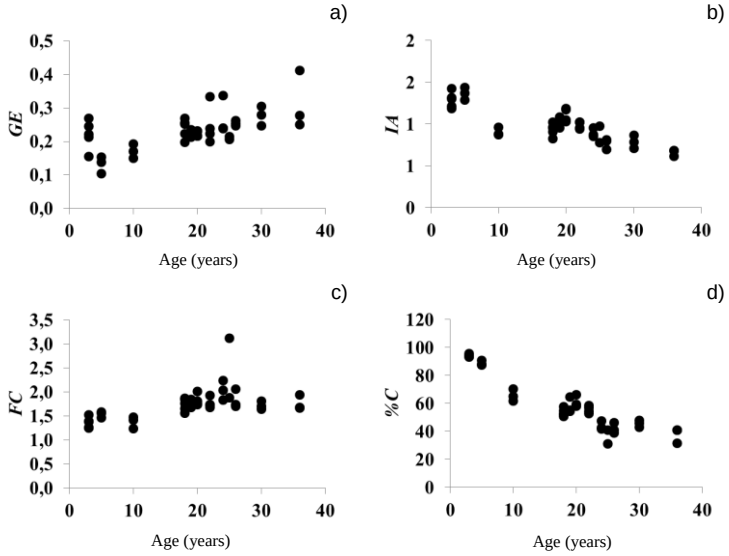

Fig. 3: Relations between morphometric variables with age of *E. guineensis* in Southern Bahia (a: Degree of slenderness; b: cover index; c: crown shape; d: canopy proportion).

There are only a few records regarding palms. Matos (2010) analyzed morphometric characteristics of inajá (*Attalea maripa* (Aubl.) Mart.) in silvipasture systems in northeastern Pará. The author observed that canopy length, canopy diameter, canopy area, canopy proportion, cover index, and canopy shape are not influenced negatively by the plant's diameter. The degree of slenderness and protrusion index are negatively influenced by *DBH*. Canopy length and degree of slenderness are intra-related and are positively influenced by growth in total height. Canopy proportion is influenced in a negative way by stem height growth and by the height of fructification, and positively by canopy length. The index of slenderness, cover index and canopy shape are positively influenced by canopy diameter. The last one is influenced in a positive way by stem height and height of fructification, and negatively by the growth of canopy length.

Research of interdimensional relationships between lonely plants through morphometric indexes are important, once this allows forecasting required spacing by the plants throughout their development, considering the competition to which plants are subjected, besides, it is possible to infer stability, vitality and individual productivity. Thus, this can be considered a practical tool for silvicultural interventions, especially when the age of the plants are not known (Durlo *et al*., 2004).

In this study, it was possible to show that the technical rotation of 25 years currently practiced is aided by morphometric data and by other morphometric relationships. However, the spacing utilized nowadays may not be the most indicated one.

Conclusions:

The diameter growth curves (at 50 cm above ground level for stem and canopy) presented different behaviors from their respective height curves (total and stipe).

The stabilization of diameter growth curves happens around 20-25 years of age, while heights have not showed stabilization trend by the age of 36 years.

Based on the diameter growth curve it would be possible to establish the age of 20-25 years as a reference for technical rotation of this species. This reference needs to be based on fruit oil production data, which is the main objective of these stands.

Degree of slenderness raises with age. Cover index and canopy proportion decrease as plants grow older.

Considering the canopy diameter, the current spacing utilized in such stands needs to be redefined, considering a maximum density of 113 plants/ha, the equivalent to 9.8 m between line and 9 m between plants.

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