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Biometric characterization of *Campomanesia xanthocarpa* (Mart.) O. Berg. in an araucaria forest

Caracterização biométrica de Campomanesia xanthocarpa *(Mart.) O. Berg. em floresta ombrófila mista*

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ABSTRACT
The present research aimed to analyze biometric characteristics of *Campomanesia xanthocarpa* and its fruits and its fruit yield. This study was developed in araucaria forest at Irati National Forest, Paraná state. To perform this analysis, 31 individuals were selected and the total height and commercial height, diameter breast height (DBH), crown diameter, crown length, crown proportion, crown formal, salience index, range index and slenderness rate were measured. From the fruits, variables as length, width, weight and number of seeds per fruit were measured. The fruit yield was estimated by means of the fruit number per branch and the average fruit weight per tree. The species presented total height, DBH and crown diameter of 14.2 m, 32.09 cm and 9.5 m, respectively. The crown diameter is 30 times greater than DBH, and 49.71% from total height is occupied by its crown. The fruits presented 22.01 mm, 19.74 mm, 6.64 g and eight units for width, length, weight and seeds/fruit, respectively. The yield was 1.273 fruits, with 8.64 kg.tree^{-1}. The species presents slow growth, with slender crown and resistance to weathering. Its fruits had great potential for selection for commercialization.
Keywords: ecology; fruits; guabiroba; productivity.

RESUMO
A pesquisa objetivou analisar as características biométricas de *Campomanesia xanthocarpa* e dos seus frutos e a sua produtividade frutífera. O estudo foi desenvolvido em floresta ombrófila mista na Floresta Nacional de Irati, estado do Paraná. Para realização das análises foram selecionados 31 indivíduos e mensuradas as seguintes variáveis: altura total e do comercial, diâmetro à altura do peito (DAP), diâmetro e comprimento da copa, proporção e formal de copa, índice de saliência e abrangência e grau de esbeltez. As variáveis dos frutos analisados foram: comprimento, largura, peso e número de sementes/fruto. A produtividade frutífera foi estimada por meio do número de frutos/galho e o peso médio de frutos/árvore. A espécie apresentou altura total, DAP e diâmetro de copa de 14,2 m, 32,09 cm e 9,5 m, respectivamente. O diâmetro da copa é 30 vezes maior que o DAP, e 49,71% da altura total é ocupada pela copa. Os frutos apresentaram largura, comprimento, peso e sementes/fruto de 22,01 mm, 19,74 mm, 6,64 g e oito unidades, respectivamente. A produtividade foi de 1.273 fruto com 8,64 kg.árvore^{-1}. A espécie apresenta crescimento lento, com copa esbelta e resistência a intempéries do tempo. Seus frutos possuem grande potencial para comercialização.
Palavras-chave: ecologia; frutos; guabiroba; produtividade.

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INTRODUCTION

The Brazilian flora is rich in edible wild fruits, which constitute a precious genetic and cultural heritage of inestimable value (MIELKE *et al.*, 1990) and has increasingly conquered consumer preference. In this way, Brazil has a great productive potential, because there are innumerable native edible fruits not commercialized, exploited almost exclusively by local extractivism, with neither culture technology nor production for most of these species (MEDAETS, 2007).

In southern Brazil, among many native botanical families, Myrtaceae is considered one of the Neotropic's most important, recognized in many phytosociological studies as one with the greatest species richness (HASTON *et al.*, 2009). Among the various species in this family, fruit trees have great economic potential, especially for agriculture (CARVALHO, 2006).

Among these fruit species, there is *Campomanesia xanthocarpa*, popularly known as "guabiroba". It is a deciduous, mesophytic up to heliophytic, selective hygrophyte species, quite frequent in semidecidual seasonal forest, alluvial forest and montane araucaria forest (LORENZI, 2009), especially in moist soils, woods and other forest open areas with low natural fertility (CARVALHO & NAKAGAWA, 2000).

Studies were developed about the many potential healing properties of the species (LUZ & KRUPEK, 2014; VALLILO *et al.*, 2008; GOGOSZ *et al.*, 2010; HERZOG *et al.*, 2012; KLAFKE *et al.*, 2010; VINAGRE *et al.*, 2010; SANTOS *et al.*, 2009) and its nutritional fruits (VALLILO *et al.*, 2008; SANTOS *et al.*, 2009) but "guabiroba" is still consumed by only local populations, mostly *in natura*, also by wild animals.

Research about the species and its fruits biometric characterization, as well as productivity estimates in diameter breast height (DBH) classes, are insufficient, although necessary to species' management and conservation.

According to Durlo & Denardi (1998), trees' biometric variables are applied to understand interdimensional relations, rebuild each tree space in the field, evaluate the forest competition degree and yet, to give information about stability, vitality and each individual's development. Fruits biometrics is also an important tool in matrix selection as it provides relevant information for conservation and economic logging resources, allowing continuous and rational selection for production (GUSMÃO *et al.*, 2006).

Knowing these facts, this study aimed to evaluate *C. xanthocarpa* and its fruits biometric characters as well to estimate its productivity in an araucaria forest remnant.

MATERIAL AND METHODS

AREA DESCRIPTION AND SAMPLING

The study was developed in 25 permanent plots of one hectare each (totalizing 25 ha), in an araucaria forest, at Irati National Forest ("Flona Irati"), located between the municipalities of Fernandes Pinheiro and Teixeira Soares, in the Paraná state. Flona Irati has 3,495 hectares total area, 57.6% occupied by native forests.

For trees biometric characterization, fruit biometrics and fruit productivity estimation analysis, 31 individuals were selected, from 168 identified in the total area, with DBH greater than or equal to 10 cm. For trees selection, a minimum distance of 20 m between individuals was imposed, in order to reduce related individuals proximity.

TREES BIOMETRIC CHARACTERIZATION

Total height (h, meters), commercial height (h_c, meters), DBH (centimeters), crown diameter (d_{crown}, meters), crown length (l_{crown}, meters) were measured as biometric characters. With these measures, the following variables were determined: crown proportion (CP, %), salience index (SI),

range index (RI), crown formal (CF) and slenderness index (SNI), calculated by equations (1) through (5), according to Tonini & Arco-Verde (2005):

$$CP = \left(\frac{l_{crown}}{h} \right) \times 100 \quad (1)$$

$$IS = \frac{d_{crown}}{DBH} \quad (2)$$

$$RI = \frac{d_{crown}}{h} \quad (3)$$

$$CF = \frac{C_{crown}}{d_{crown}} \quad (4)$$

$$SNI = \frac{h}{DBH} \quad (5)$$

where: l_{crown}: crown length (m); h: height (m); d_{crown}: crown diameter (m); DBH: diameter breast height (cm).

Total and commercial height were measured with a 7,5 m graduated ruler; heights above this were estimated. Crown length was calculated as the difference between total and commercial heights. DBH was obtained by using an ordinary circumference tape measure, as medium crown diameter was determined by two measures, in fixed directions (North/South, East/West), with a 20 m measuring tape.

The individuals per hectare optimal density (N.ha^{-1}) was determined by equations (6) and (7), according to Batista *et al.* (2014). In this analysis, it was intended to determine the necessary space for harvest or in areas under management, the necessary space to allow the growth of the species without competition.

$$CA = \frac{\pi}{4} \times (d_{crown})^2 \quad (6)$$

$$N = \frac{10.000}{CA} \quad (7)$$

Where: CA: crown area (m^2); d_{crown}: crown diameter (m); N: trees number per hectare.

Biometric data were evaluated by descriptive analysis. Correlation between these variables was evaluated by Pearson's correlation coefficient (*r*). This analysis was made in order to model some species variables. Statistical analysis was performed in PAST software (HAMMER *et al.*, 2001).

FRUITS BIOMETRIC CHARACTERIZATION

At the fruiting period (October), 30 fruits per selected individual were collected with a trimmer (LUZ & KRUPEK, 2014) and all were conditioned in plastic recipients for further analysis. Fruits were washed and dried, and the following biometric characteristics were measured: length (mm) and width (mm) with a digital caliper; fresh weight (g) in a precision ± 0.01 digital scale; and seed per fruit

counting (LUZ & KRUPEK, 2014). For the analysis of the biometric characteristics, the descriptive statistic was used and the correlation analysis was performed using the Pearson coefficient (r) in the PAST software (HAMMER *et al.*, 2001).

PRODUCTIVITY ESTIMATES

For productivity analysis, three tree branches of each selected individual were chosen randomly and the fruit number counted. Total fruits per tree were estimated by simple proportion, based on trees branches number (FALCÃO *et al.*, 2000). Quantification of trees branches was done in species dehiscence time, when there are no leaves, in order to facilitate counting. Branches counting, as well as fruits counting on branches were made by field observations with binoculars.

Productivity was estimated by multiplying average fruit weight by total estimated fruit number, resulting as total produced fruit weight by tree, which productivity was distributed in DBH classes. Four classes (of 10 cm) were considered: class 1 (10 – 20 cm), class 2 (20 – 30 cm), class 3 (30 – 40 cm) and class 4 (equal to or greater than 40 cm).

RESULTS

BIOMETRIC CHARACTERIZATION OF *C. XANTHOCARPA*

Data on biometric characteristics of *C. xanthocarpa* are presented in table 1. The species presented, on average, 14.3 m total height, 32.09 cm DBH and 9.5 m crown diameter. Crown proportion revealed that 49.71% from total tree height is engaged by the crown and that it is also 30 times higher than DBH, as noted by salience index.

Table 1 – Biometric *Campomanesia xanthocarpa* variables descriptive statistics in araucaria forest remnant, at Irati National Forest, Paraná state.

Variables	Minimum	Mean/SD	Maximum	Variation coefficient (%)
Total height (m)	8.0	14.3±3.90	24.4	27.26
Commercial height (m)	4.5	7.2±2.15	13.8	29.85
Diameter at breast heigth (cm)	15.76	32.09±11.01	49.02	34.31
Crown length (m)	3.0	7.2±2.26	10.6	31.31
Crown diameter (m)	5.0	9.5±2.98	14.5	31.44
Crown proportion (%)	37.50	49.71±7.10	62.32	14.28
Salience índex	0.17	0.30±0.05	0.43	17.74
Range índex	0.42	0.66±0.12	0.86	18.56
Crown formal	0.50	0.77±0.11	1.10	14.83
Slenderness índex	0.34	0.47±0.09	0.67	18.43

SD: standard deviation.

Minimum and maximum crown formal (0.50 through 1.10) showed that there are little differences between individuals or, in other words, that most trees (97%) have slender crowns (crown formal < 1). About slenderness index, no trees presented values higher than one, meaning that this species has high weather resistance.

Using the average crown diameter (9.5 m), we could infer about free competition optimal density, being necessary a 76.84 m² planting area for each individual, or 191 trees per hectare, if there were plans to manage in an homogeneous plantation.

Correlations for biometric variables of *C. xanthocarpa* are in table 2. All biometric variables were significant at 1% probability, and had high correlation with each other. Commercial height was an exception, having median correlation with all biometric variables.

Table 2 – Pearson (*r*) correlation between biometric variables of *Campomanesia xanthocarpa* in an araucaria forest remnant, at Irati National Forest, Paraná state.

Variables	Diameter at breast height	Crown diameter	Total height	Commercial height	Crown length
Crown diameter	0.90**	-	-	-	-
Total height	0.87**	0.79**	-	-	-
Commercial height	0.57**	0.46**	0.88**	-	-
Crown length	0.95**	0.93**	0.89**	0.56**	-
Crown proportion	0.57**	0.64**	0.25ns	-0.24ns	0.66**
Salience index	-0.47**	-0.07ns	-0.39*	-0.37*	-0.32ns
Range index	0.29ns	0.57**	-0.02ns	-0.37*	0.31ns
Crown formal	0.15ns	-0.18ns	0.23ns	0.22ns	0.19ns
Slenderness index	-0.73**	-0.62**	-0.32ns	0.03ns	-0.59**

** significant correlation at 0.01; *significant correlation at 0.05; ns no significant correlation.

Biometric variables as crown proportion, salience and slenderness indexes presented significant correlation with DBH, resulting in negative correlation with salience and slenderness indexes. Total height presented significant correlation only with salience index. Crown formal presented low and no significant correlation with all biometric variables evaluated.

FRUITS BIOMETRIC CHARACTERIZATION

Four of 31 selected trees had not entered in reproductive phenophase, so their fruits were not collected. Results presented in Table 3 are from 27 individuals evaluated with reproductive phenophase. Fruits biometric phenophase presented average 22.01 mm width, 19.74 mm length, 6.64 g fresh weight and eight seed units per fruit. All biometric variables presented great variability.

Table 3 – *Campomanesia xanthocarpa*'s fruits biometric variables descriptive statistics in an araucaria forest remnant, at Irati National Forest, Paraná state.

Statistics	Width (mm)	Length (mm)	Fresh weight (g)	Seeds/fruit
Minimum	13.11	12.57	1.90	5.00
Mean	22.01	19.74	6.64	8.34
Maximum	32.34	28.54	20.00	12.00
Range	19.23	15.97	18.10	7.00
Standard deviation	3.22	2.98	3.02	1.18
Standard error	0.11	0.10	0.11	0.04
Variation coefficient (%)	14.61	15.10	45.57	14.09

Biometric variables correlation referred results are in table 4. All variables were significant at 1% and presented high correlation with each other. Seeds/ fruit was an exception, with a low correlation with all evaluated variables.

Table 4 – Pearson (r) correlation between biometric variables of fruits in *Campomanesia xanthocarpa* in an araucaria forest remnant, at Irati National Forest, Paraná state.

Variables	Width (mm)	Length (mm)	Fresh weight (g)	Seeds/fruit
Length	0.91**	**1**		
Fresh weight	0.92**	0.89**	**1**	
Seeds/ fruit	0.21**	0.14**	0.19**	**1**

** significant correlation at 0.01.

FRUITS PRODUCTIVITY

In table 5, DBH 10-20 cm class presented the less estimate for fruit number, as well as the less average weight per tree (930 fruits and 4,47 kg.tree^{-1}, respectively), if compared to other DBH classes. This happened because, in this class, crown length was smaller and, consequently, had less branches, and less productivity, compared to other classes.

Table 5 – Fruit yield estimate of *Campomanesia xanthocarpa*, by DBH class in an araucaria forest remnant, at Irati National Forest, Paraná state.

DBH class (cm)	Fruit number	kg.tree^{-1}
10-20	930	4.47
20-30	1030	7.45
30-40	1431	9.12
≥ 40	1488	10.91
Mean	**1273**	**8.64**

The class higher than 40 cm presented higher productivity (1488 fruits, and 10.91 kg.tree^{-1}). These values are explained by larger crown diameters, highlighting their productivity, compared to other classes.

DISCUSSION

C. XANTHOCARPA BIOMETRIC CHARACTERIZATION

Data about maximum total height and DBH variation in this species were reported by Vallilo *et al.* (2008) and Lorenzi (2009), which described that *C. xanthocarpa*'s total height may vary from 10 to 20 m, while maximum DBH varied from 50 to 60 cm. In this study, DBH (49.02 cm) is inside literature's maximum limit, but maximum total height (24.40 m) is higher than values found in publications. However, data about biometric studies were not found.

According to Tonini & Arco-Verde (2005), crown diameter and length show positive correlations as well as DBH and total height showed that those variables rise as these rise too. The authors still reported that high correlations between crown diameter and DBH are indicators for site quality. The species also presented, not only positive values, but also high correlation for DBH, related to crown diameter (0.90) and length (0.95), as for total height regarding to these variables (0.79 and 0.89, respectively).

Negative correlations for salience index and slenderness index with DBH and total height showed that these variables tend to decrease while DBH and total height increase (TONINI & ARCO-VERDE, 2005). Correlation between salience index with DBH and total height was medium (-0.47 and -0.39, respectively). Thus, correlation between slenderness index was considered high for DBH (-0.73), but low and no significant for total height (-0.32). This negative correlation was also observed by Durlo (2001), for *Cabralea canjerana* (Vell.) Mart. located in natural forests at Rio Grande do Sul state and by Tonini & Arco-Verde (2005), in an homogeneous plantation in Roraima state, for *Bertholletia excels* Bonpl. (castanheira-do-brasil), *Carapa guianensis* Aubl. (andiroba), *Tabebuia avellanedae* Lorentz ex Griseb. (ipê-roxo) and *Hymenaea courbaril* L. (jatobá).

Among the biometric variables evaluated, crown proportion indicates the tree competition degree suffered in the past (DURLO & DENARDI, 1998). Based on this, it is possible to verify that evaluated individuals suffered low competition, as medium crown proportion was 49.71%.

Salience index shows how many times crown diameter is bigger than DBH (ORELLANA & KOEHLER, 2008). It can be applied as an indicator for the necessary space each tree needs for growing without competition, up to reaching a determined diameter (DURLO & DENARDI, 1998). Applying 0.30 for medium salience index, and accepting it is fixed even if there is changing in trees

dimensions, considering an individual with DBH = 32.09 cm, there would be necessary a 72.84 m² area for a tree growing, which crown diameter would be 9.63 m (32.09 x 0.30).

Tonini & Arco-Verde (2005) reported that, in tropical natural forests, salience index varies from 14 to 28; greatest volume growth species presents values from 15 to 20, and those with values higher than 25 are species with low growth. Based on these informations, this species can be characterized as a low growth one, as crown diameter and DBH relation was 30.

Besides salience index, range index also can be applied to indicate the best moment for crop logging, because it considers height as an interest variable. So, taking medium range index value (0.66) for an individual, with 14.3 m total height growing without competition, it would be necessary a 69.96 m² area. As Orellana & Koelher (2008), this index can be applied here, when there is a high correlation between crown diameter and total height. In this study, correlation between crown diameter and total height was 0.79, a condition that allows it to apply in this species' forestry.

Crown formal indicates crown flattening degree. An index next to 1 indicates a round crown, lower than 1 a slender crown and higher than 1, a flatten crown (ORELLANA & KOEHLER, 2008). In this study, a variation between 0.50 to 1.10 was verified; however, 97% of the sampled individuals presented values lower than 1, characterizing the species crown as slender.

According to Tonini & Arco-Verde (2005), a total height/ DBH relation by slenderness index higher than 1 shows bigger competition, because diameter growth is reduced, compared to height. It is also applied to evaluate climate (mostly by wind) changes susceptibility. As Durlo & Denardi (1998) state, the higher the slenderness index, the greatest susceptible to wind damage the tree will be. In this research, values varied from 0.34 to 0.67, showing this species has high wind damage resistance and low competition with other species.

FRUITS BIOMETRIC CHARACTERIZATION

Luz & Krupek (2014) evaluated the same species in Porto União municipality, Santa Catarina state, and reported a great range for all variables studied, results that were also observed in this research. They found 11 to 24.8 mm for fruit length, 12.4 to 28 mm for fruit width, 1.6 to 11.4 g for fruit fresh weight and 1.3 to 3.8 seeds per fruit. For length and width, the range was close to the information found at that study (12.57 to 28.54 mm; 13.11 to 32.34 mm, respectively), however, weight and seeds per fruit differed (1.90 to 20 g and 5 to 12, respectively).

Herzog *et al.* (2012), evaluating *C. xanthocarpa* eight matrices, in three different maturation stages, in Marechal Cândido Rondon municipality, Paraná state, verified that there was no significant difference between maturation stages for fruits fresh weight, length and width, with medium values as 4.78 g, 18.26 mm and 18.93 mm respectively, with seeds per fruit equal to 10, numbers really close to found in this research (6.64g; 22.01 mm; 18.93 mm; 8 units).

Oliveira (2009) reported that fruits biometry can be applied to identify species in same genus, but with similar morphologic features. The author evaluated two *Campomanesia* species (*Campomanesia adamantium* (Cambess.) O. Berg and *Campomanesia pubescens* (Mart. ex DC.) O.Berg). *C. adamantium* fruits showed length and fresh weight higher than *C. pubescens*.

Also, Oliveira (2009) got medium values of 19.39 mm for width, 18.30 mm for length, 4.15 g for fresh weight and 2.02 units for seeds per fruit in *C. adamantium*; 17.30 mm, 16.34 mm, 2.63 g and 2.18 units for *C. pubescens*. Comparing these results with *C. xanthocarpa*, all results were higher. Oliveira (2009) also reported *C. adamantium* revealed higher variability for analyzed features, which favored promising materials selection, in order to market the fruits in the future. This research also showed range variables for *C. xanthocarpa* were high, showing great potential to select matrices in forestry.

Luz & Krupek (2014) evaluated the fruits biometric variables correlation in *C. xanthocarpa* and found a high correlation between the variables analyzed, agreeing to the results found here.

FRUIT PRODUCTIVITY

Despite the importance of the results for productivity, no literature data was found about *C. xanthocarpa* so there wasn't any possibility to evaluate if its sampling satisfied the species' fruit productivity.

It is important to highlight that the results found here are estimates, brought by medium fresh fruit weight from each selected tree for the research, with different kg.tree^{-1} productivity, higher or lower, as seen in that the medium fresh weight range was high (1.90 to 20 g).

Four of seven individuals at class 1 (10 to 20 cm DBH) selected for this analysis had not presented the reproductive phenophase. This kind of information is extremely relevant, mainly when there is a wish to know fruit productivity per hectare. It is not only important to know how many individuals are present in an area, but how many are in reproductive phenophase, in order to obtain reliable data about general fruit productivity from the site.

CONCLUSION

The species presented high variability for the biometric variables evaluated (total height, DBH, commercial height, crown length and crown diameter). Species biometric variables presented high and significant correlation between each other. This can be applied in this species modeling studies. Biometric variables revealed also that this species has low growth, slender crown, with high wind resistance and low competition.

All fruits biometric variables, with the exception of seeds per fruit, presented high correlation between each other, showing the fruit shape a regular proportion. Fruits productivity was higher in DBH class equal to or greater than 40 cm.

Fresh weight and fruit length measures indicate great variability, with potential for selecting promising materials for commercialization.

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