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Mathematical Models to Estimate Leaf Area of Melon Plant Cultivar Hale's Best Jumbo at Different Phenological Stages Using Linear Measurements

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Abstract
Melon plants cv. Hale's Best Jumbo Cantaloupe were cultivated under field conditions in Sinop - MT in order to develop mathematical models based on linear measurements which allow the estimation of leaves area. Were collected four times leaves, first collection at 20 days after sowing (DAS) with 45 leaves, second collection at 30 DAS with 40 leaves, third collection was performed 40 DAS with 40 leaves was performed 50 days with 33 sheets. 45 leaves in the first test at 30 days after sowing (DAS), 40 sheets in the 2nd collection at 40 DAS, 40 leaves on the 3rd collection at 50 DAS and 33 leaves on the 4th collection at 60 DAS. Linear measurements were taken along the length of leaf central vein (L) and the largest width (W) perpendicular to the central vein. At each time was determined leaf area (LA) using a LI-COR LI-3100 area integrator. The data length and width and product of L by W were considered the independent variable (x) and real leaf area (LA) as dependent variable (y). Were performed linear regression analyzes for each of the seasons and the length and width of the sheet and the product LW. From the results it is concluded that: a) the length of the central rib does not allow to accurately estimate the leaf area of melon, b) the greatest width of the sheet provides a better estimative of leaf area, c) the phenological stage 3 provides the best estimate of the foliar area and d) the model that best estimates leaf area of melon is Y = 10.284 x - 16.404 value of r = 0.8627.

Keywords: *Cucumis melo*, Growth analysis, leaf area integrator, nondestructive method, linear regression.

Introduction

Historically, melons (Cucumis melo L.) are one of the freshest fruit exported by Brazil. In 2012, had been exported 181,700 tons of fruit, generating revenues of $ 122 million, surpassed only by grape, thus occupying the second place in the Brazilian export basket fruit (IBRAF 2012). The Brazilian melon production has a significant advantage in marketing, because the height of the season, from September to January is the time of global harvests, resulting in greater profitability.

Melons are characteristically by presenting high sugar levels and low acidity (Bonetti et al. 2010). These parameters are many times controlled by temperature, fertilization levels (N and K), and overall by high photosynthesis ratio. One of the parameters to increase photosynthesis efficiency is correlated to growth parameters and leaf area is well representative in melons. Maracajá et al., (2008), say that must be carried out studies related to growth parameters of this species, emphasizing leaf area evaluation because in the leaves is the place that happens many important functions as transpirations and photosynthesis. Acknowledge of leaf area is important to evaluate growth studies, nutritional and phenological stages leading to use to correct techniques to a good practice cultural (Marcolini et al., 2005).

According to Costa (1999), melon leaf area is an important measurement to evaluate photosynthetic plant efficiency and your final production. So, your evaluation during all cultural cycle is very important with the objective of create a correlation with a model to explain growth and development and thereafter productivity and total yield of the culture (Teruel, 1995; Nascimento et al, 2002).

Silva et al. (1998) cite that non destructive methods to estimate leaf area, quickly, easy to be executed and that show accepted precision levels are useful to study plant growth on Field conditions. Furthermore, non destructive methods make it possible to perform repeated sampling during the development of the crop, reducing the experimental error associated with destructive methods.

According to Benincasa (1988) there are several methods that can be used to leaf area measurements, being these classified in: destructive and non destructive, direct or indirect. Destructive methods need removed plant parts to be analyzed, and in some cases is not possible due to any kind of applied studies.

Estimative leaf area can be done using relation between linear dimensions and their area, standing out as a simple alternative, low cost and with easy access, needing just millimeter ruler and associate calculus. There by, leaf area can be estimated using dimensional leaf measurements , resulting in good correlations with superficial leaf using regression analyses with real leaf area (RLA) and linear leaf parameters (Marcolini et al., 2005).

The methods are composed by length measures, width and area sampled leafs and them regression coefficients that list linear measures with leaf area. Theses equations have been used with success on great crops as; Niagara Rosada vine (Pedro Junior et al., 1986), pumpkins (SILVA et al., 1998), strawberry (Pires et al, 1999), yellow melons (Nascimento et al., 2002), mammon (Severino, 2004) and cabbage leaf (Marcolini et al., 2005).

Although there are in the literature mathematical models for predicting leaf area of melon based upon linear measurements, different environmental conditions and cultivars, as well as anatomical differences in the leaves cause they are not suitable for the conditions of Sinop – MT

The aim of this study was evaluate linear mathematical models to estimate leaf from linear measurements of leaf at different growth stages of cantalupensis melon cv. Hales Best Jumbo.

Methods

The study was carried out in the experimental area from Horticultural crop from Federal University of Mato Grosso - *Campus* Sinop–MT, localizated to GPS position 11°50'53'' S and 55°38'57" W, with elevation of 380m. (Pinto, 2012). The region has annual rainfall next to 2000mm and a variation of evapotranspiration around 1300 e 1400mm. Climate is classified second Köppen classification as "AW", with well-defined seasons: rainy from October to April and dry from may just to september (Lima et al., 2013). The region soil is classified as dystrophic red yellow clay loam latosol (Oxisol) (Embrapa, 2006).

The soil acidity correction was performed 60 days before planting by interpreting results soil analysis of the area being incorporated 2.5 t ha^{-1} from dolomitic limestone (130 g kg^{-1} of MgO, 390 g kg^{-1} CaO and PRNT 67%), in order to increase base saturation to 80% and the magnesium content of 9.0 $mmol_c$ dm^{-3} (Souza e Lobato, 2004).

At 60 days after liming proceeded to the opening of the pits with dimensions of 30 x 30 x 30 cm, in which they performed a basic fertilization applying 50g 04-14-08 formulated (N-P_2O_5 -K_2O).

Sowing was done on February 3, 2012, directly in the pits, the same being spaced 1.5 m x 0.5 m. Seeds of melon cv. Hale's Best Jumbo (Topseed ®), and depositing two seeds per hole to a depth of 2 cm were used. When the seedlings reached 10 cm held thinning were made leaving one plant only.

The plants were vertically trained, using yarn raffia (trellised) trapped two strands of steel wire # 14 stretched parallel to the ground to 0.05 m and 1.7 m in height. The wire strands were properly attached to the wooden fence posts spaced 4.0 m. The fixing of the stems of the plants in the wire raffia was the same as if developed, this procedure being carried out once each two days. The plants were irrigated using drip irrigation.

Pest control management was done with sprays of chlorothalonil and metalaxyl-M at intervals of 15 days after plant emergence

The leaves were picked up following methodology proposed by Mota et al, (2010) to define the times of leaves harvest considering the following phenological stages of the crop: I - Initial (7 to 22 days), II - vegetative growth (22-40 days), III - fruiting (41-58 days) and IV - maturing (59-70 days).

Four picked up samples of leaves were gather, with 45 leaves at 20 days after sowing (DAS), 40 leaves at 30 DAS with 40 sheets in the 3rd collection at 40 DAS and 33 leaves on the 4th collection at 50 DAS due to senescence the leaves were picked up, few could be selected on Wednesday reviewed.

After harvesting, the leaves properly identified were carried out to the laboratory, where were performed the measurement of the area of each leaf using a leaf area integrator model LI-3100C (LICOR®). Then, each leaf was measured properly identified with the use of a ruler graduated in millimeters, the length (**L**) along the central rib (taken from the apex to the junction of the blade with petiole) and width (**W**) defined as largest dimension perpendicular to the alignment of the midrib.

The length measures (L), width (W), leaf area (LA) and the product of length by width (LW) were submitted to regression analysis using the statistical software LAB Fit (Silva and Silva, 2004). Criteria used to select the functions that best correlated the linear measurements with leaf area were: the number of parameters of the equation, correlation coefficients, and dispersion analysis.

Results and discussions

In relation to leaf width (W), is displayed in Figure 1, that collections in the initial stage (20 DAS) and early vegetative growth (30 and 40 DAS) did not allow an accurate estimation of melon leaf area, while collecting the fruiting stage (50 DAS) allowed the best estimate of the leaf area of melon. Thus, based to regression analyses the model: **Y = 9.72 W – 7.358** was the best to explain on fact. These results are similar to those verified by Nascimento et al., (2002), whose best leaf area estimates whose estimated area were obtained at 34 and 50 DAS, the model that best expresses the relationship between leaf area and width of the leaves is $LA = 0.826W^{1,89}$. Similarly, Tivelli et al. (1997) showed that the estimated pepper leaf area measuring the width of the leaves. A fact to be noted is the difficulty in obtaining accurate measures of melon leaves due to the formation of its leaves, which have cordiform shape with jagged edges that make it difficult to obtain accurate linear measurements.

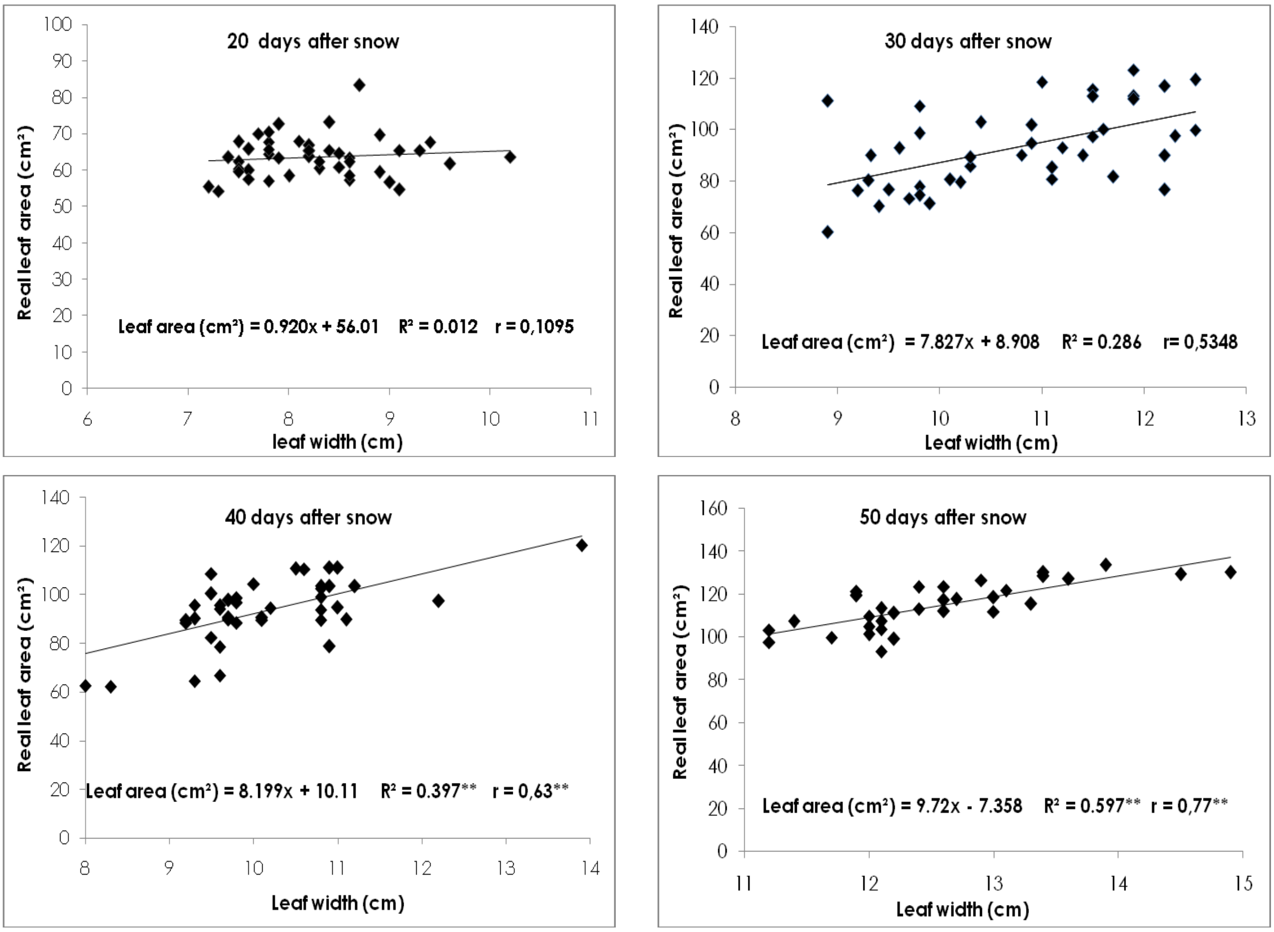


Figure 1 – Linear regression models to estimate leaf area using the width perpendicular to the midrib at different growth phenological stages of melon. (Modelos de regressão linear para estimativa da área foliar utilizando a largura perpendicular à nervura central das folhas em diferentes estádios fenológicos do meloeiro). UFMT. Sinop-MT, 2012.

Regarding to the Figure 2 linear fit models are presented for relative leaf area to the length of the midrib the leaves were picked up of melon. It is observed that this collection at 20 DAS allows not accurately estimate leaf area of melon, while the collections at 30 DAS enables better estimation of leaf area of melon, then the collections at 40 and 50 DAS. Thus, the results from regression analyses show a linear regression as we propose the model: Y = 15.54 L - 3,5,53, whose value of the correlation coefficient of 0.836, indicating a good correlation between the model variables. These results are in accordance to obtain by Lopes et al. (2007) whose reduction in the amounts of R ² in the stage of harvest of the fruit (57 to 67 DAT) was more pronounced when the equations were adjusted from the length of the leaf. These results points that reproductive period, the length of the leaf is larger than the variation width. Therefore, to better estimate leaf area of melon this stage should be used measurements of maximum leaf width.

Nascimento et al., (2002), showed a higher accuracy in estimating the leaf area with width measurements relative to leaf length. They attributed these results to the insertion of the petiole on the leaf surface and also its cordiform shape, which makes it difficult to measure the length of the leaf by increasing the errors associated with their determination. Furthermore, they cite that the width of the leaf remains more stable during the melon cycle.

Similarly, Pires et al. (1999) estimating the leaf area of strawberry, a plant whose leaves are heart-shaped, found that higher correlation of leaf area with its width due to this dimension is more stable and has less possibility of error in your measurement, which resembles to the study of Tivelli et al. (1997) observed that the bell pepper is a high correlation between L and W X L.

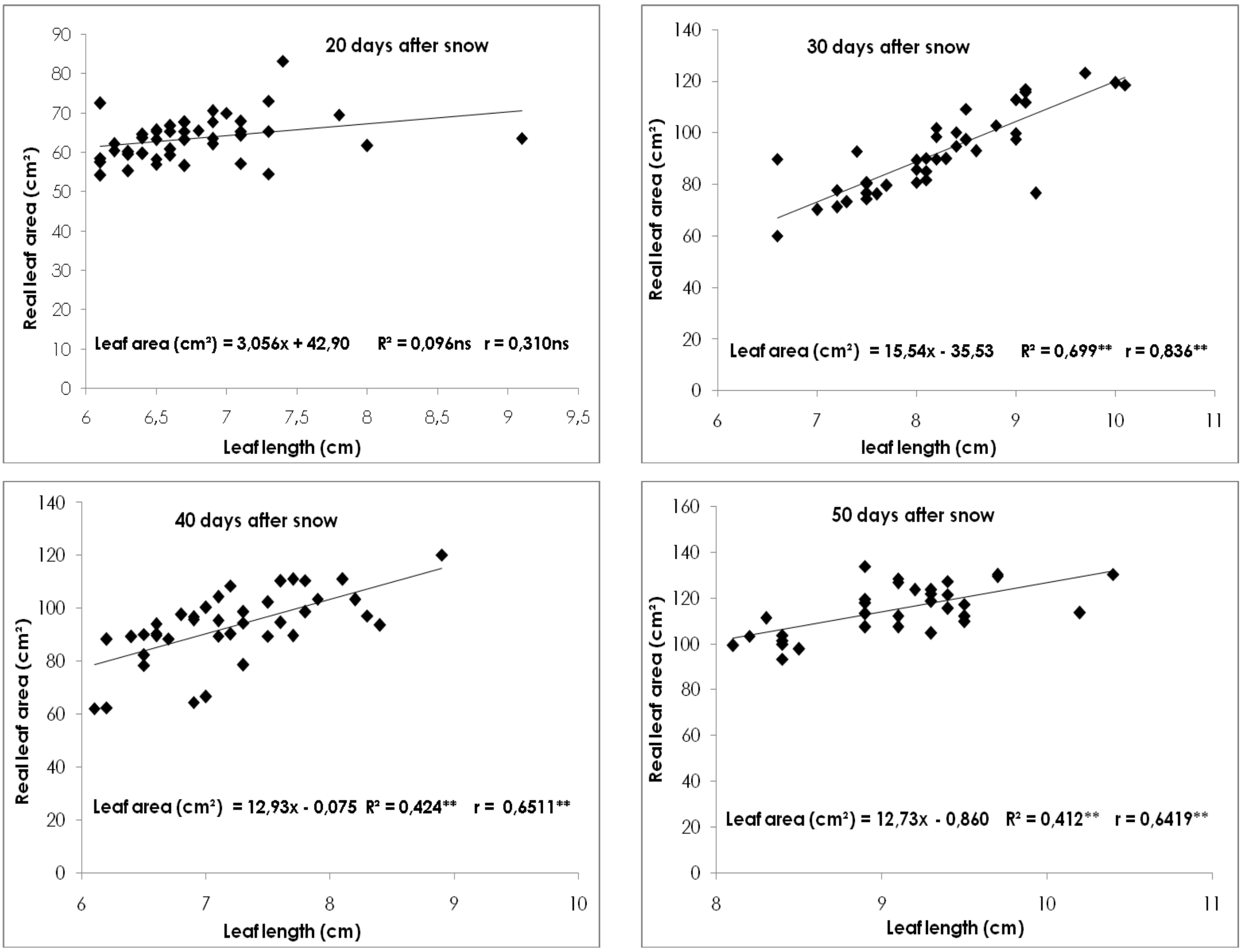
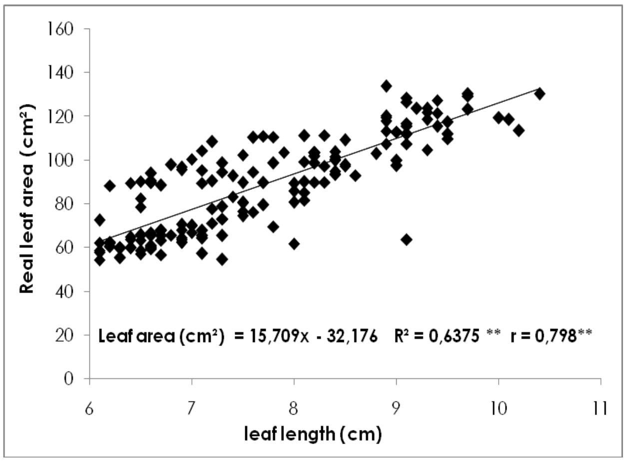


Figure 2 – Linear regression models to estimate leaf area using the length of the midrib the leaves at different growth phenological stages of melon. (Modelos de regressão linear para estimativa da área foliar utilizando o comprimento da nervura central das folhas em diferentes estádios fenológicos do meloeiro). UFMT. Sinop-MT, 2012.

Then, linear models were adjusted for leaf area from length and width the leaves were picked up , regardless of the time of collection (Figure 3). Comparing the models it is found that the model that best estimates of melon leaf area is employing a measure of the width perpendicular to the midrib (Y = 10,537 C - 18.861, R2 = 0.746 **, r = 0.86 **).

Marcolini et al., (2005) pointed out that although the equations with the product CL showed a better fit and ability to estimate leaf area of cabbage, models based on a single leaf offers advantages such as shorter time period to leaf measurement and greater efficiency in data collection, as they only require a single measure. Thus, due to lower levels of significance of the F test of the models and good correlation observed coefficients for the equations of adjustments based on leaf width, this parameter can be used to estimate leaf area of collard greens.



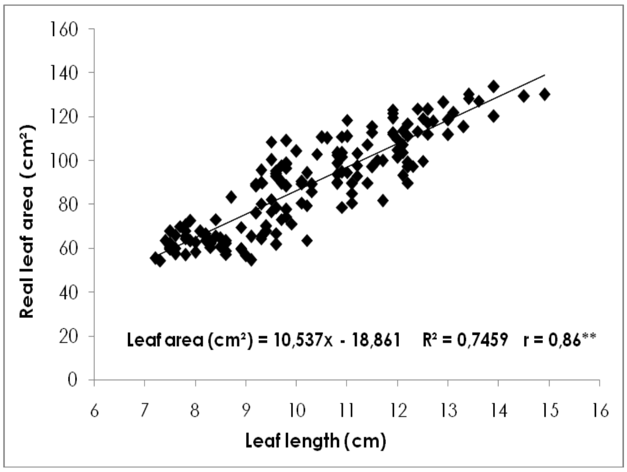


Figure 3 – Linear regression models for leaf area using the length and width of the leaves of melon. (Regressão linear para a área foliar utilizando o comprimento e a largura das folhas do meloeiro). UFMT. Sinop-MT, 2012.

This result is also indicative that in the growing season when the photoassimilates are displaced only to the leaves, there is less variability in the leaves. In the reproductive period, there was greater variability in the size and shape of the leaves, because the displacement of assimilates for fruit resulted beside of reduction in leaf area in formation, reduction in emission of new leaves and senescence of older leaves.

Conclusions

In the conditions which were carried out this study concluded that:

a) The length of the midrib and leaf width leads to precisely estimate the melon leaf area.
b) The width of the leaf enables a better estimate melon leaf area.
c) Leaves picked up during vegetative development enables a better estimate of melon leaf area.
d) The width the leaves were picked up allows better estimate leaf melon area estimates and the adjustable model is: Y = 10.284 L - 16.404, r = 0.8627.

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