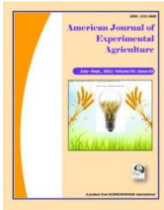

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Estimates of Leaf Area of *Curcubita moschata* Duch. Based on Linear Measures and Degree-days in Planting of Winter in the Central-Western Region of Brazil

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Authors' contributions

This work was carried out in collaboration between all authors, being distributed as follows: authors APS and ACS designed the study, wrote the protocol and wrote the first draft of the manuscript. Authors AAT and MES reviewed the experimental design and all drafts of the manuscript. Authors FFM and WFBD managed the plant analyses of the study. Authors APS and ACS performed the statistical analysis. All authors read and approved the final manuscript.

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ABSTRACT

Aims: Evaluate the evolution of leaf area of the pumpkin cv. Menina Brasileira Precoce by simplified estimation models based on linear measurements of the blade leaf.
Study Design: Field experiment, distributed in randomized block design with four replicates of four plants each block. The sowings occurred at intervals of 10 days during the winter period to 5 planting dates (which are recommended due to the lower incidence of disease in plants), being measured 80 plants.
Place and Duration of Study: Experimental Area of the Vegetal Production, University Federal of

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Mato Grosso, Sinop, Mato Grosso State (transition Amazon-Cerrado region), between June 2013 and December 2013.
Methodology: Were obtained linear measurements (length, width and transverse) to estimate the total leaf area (LA) of plants from pumpkin cv. Menina Brasileira Precoce. The linear, polynomial and exponential simplified models to estimation of LA and the number of leaves in different size classes and position in the branches of the plant. The coefficients of the regressions were adjusted by maximizing the coefficient of determination (R^2), being also employed statistical indicative MBE, RMSE, adjustment index and position value for evaluating the statistical performance of the models generated.
Results: Were generated 29 simplified models estimative of LA, with R^2 ranging from 0.2138 to 0.7232, with maximum underestimation of 3.73 cm² and overestimation to 9.52 cm², scattering ranging from 10.46 to 17.59 cm² and adjustments above 46%.
Conclusion: The leaf area of pumpkin cv. Menima Brasileira Precoce can be predicted by equation $LA = 0.2720 (L + WL)^{1.8467}$ with precision, simplicity and practicality on the field cultivated.

Keywords: Pumpkin; leaf area estimation; non-destructive method; statistical indicatives.

1. INTRODUCTION

The pumpkin (*Cucurbita moschata* Duch.) has significant importance in Brazilian agriculture, especially in the traditional and family agriculture because it has plenty of uses [1]. Depending on their nutritional, social and cultural value, yet it is necessary to know the possible effects of changes in production techniques (planting fertilization and/or mulching, irrigation, thinning of fruits and phytosanitary treatments) together with the determination production cycles (establishment of conducive to the cultivation seasons), estimates of crops, harvest planning, storage and disposal, among others [2,3].

The pumpkin is tropical plant, typical warm weather, which has favoured its growth and development when the average air temperature between 18 to 24ºC, even tolerating so satisfying higher temperatures [4,5]. Its adaptation adaptability in areas with large thermal and hydro variability and ease of production given the low demand for cultural techniques, allow it widely on the national scene [3]. In general and like all plants, its production is affected by weather conditions, especially in relation to solar radiation, air temperature and precipitation, because their interactions can act to delay or accelerate the growth and development of plants.

According Maller et al. [6] the leaves are responsible, among other functions, for most of the light energy interception, transpiration and production of photoassimilates. Thus, the higher the growths of the aerial part of the plant and leaf development are expected best assimilation and utilization of radiation [7]. The expression of the crop potential yield is dependent of the leaf area as it influences in photosynthetic process due to the light interception and its conversion into chemical energy of light, which in turn, is function of the number, size of the leaves and permanency time in the plant. Furthermore, these relationships interfere in ground cover, competition with other plants, specific surface evapotranspiration and aerodynamic resistance of the canopy, among other interactions with the environment [8].

In general, accurate and simple non-destructive methods for estimating leaf area are critical to many physiological, ecological, horticultural and agronomic studies. Numerous non-destructive methods have been reported in the literature for this purpose, but most either rely on complex sets of measurements and mathematical models or based in the computer analysis of digital photographs, the accuracy of which can be affected by camera angle and resolution and analysis software, among other factors [9].

Under the conditions of the Brazilian horticulture, the study of plant growth in the field comes requiring the evaluation of non-destructive methods, which can show the plant leaf area quickly and accurately [10]. According to Souza et al. [8], the use of simplified methods to estimate leaf area through the relationship between measures of the leaves and their leaf area, allows at preservation of the plant and performing several measures over its development.

Studies based on non-destructive methods have been used to estimate leaf area of some variations of the pumpkin, as "Tetsukabuto" [10] and Italian Zucchini [11]. Use of this technique allows using several samples at different stages of growth of the same plant, thus enabling the reduction of errors contained in destructive sampling [8,10].

Silva et al. [10], worked with non-destructive techniques to estimate the leaf area of pumpkin cv. Tetsukabuto in field and greenhouse, employing linear measures of length and width on the leaves and found that there were differences among models suitable for different environments and recommended for farming practices the simple mathematical models with only one variable. The researches on estimating leaf area of pumpkin are rare and are not recommended for applications on different cultivars, growth and crop management. This behavior stems from the difficulty in performing routine monitoring of the rapid leaf expansion of culture, without definitions of the spatial patterns of emission of new leaves.

In this context, objective was generate and validate simplified models to estimate leaf area based on linear measures, together with the assessment of leaf area evolution of pumpkin cv. Menina Brasileira Precoce, in soil-climatic conditions of Sinop, Mato Grosso, Brazil (transition Amazon-Cerrado region).

2. MATERIALS AND METHODS

The experiment was conducted between June to December 2013 in the experimental area of Plant Production at the Federal University of Mato Grosso, Sinop Campus, located in the 11º85 'S and 55º38'57' W, with an altitude of 345 m. The soil in the experimental area is classified as Yellow Dystrophic Oxisol. The climate according to the Koppen classification is Aw (Tropical climate) with two defined seasons: Dry (May to September) and rainy (October to April), with average monthly temperatures ranging between 22.96 and 25.76°C and rainfall and evapotranspiration annual approximate of 1974 and 1327 mm year^{-1}, respectively [12].

The pumpkin cultivar evaluated was ‘Menina Brasileira Precoce’, which has a cylindrical shape with neck, bark green with dark streaks, with initial harvest varying of 60 at 70 days after sowing (DAS) (Fig. 1). The experiment conducted in four blocks with six treatments (planting dates in winter) and four replications of four plants per block. The sowings were made in 05/06, 15/06 25/06, 05/07, 15/07 and 25/07/2013, in plantation pits of 0,4 x 0,4 x 0,4 m, in the depth of 4.0 cm, through the distribution of three seeds per pits and thinning at 25 DAS (only one plant per pit). The spacing used was 2.0 x 2.0 m between rows and between plants.

Fig. 1. Phenological stages of pumpkin cv. menina brasileira precoce: (1) emergency; (2) male floral button; (3) female flower button; (4) male flower open; (5) female flower open; (6) fruits at harvest time

The application of lime and fertilizers of the soil were made in the pit based on soil analysis. Were applied 150 kg ha^{-1} P_2O_5, 60 kg K_2O ha^{-1} and 60 kg ha^{-1} of N. The application of P_2O_5 was only in the fertilizer, whereas K_2O and N were applied in three instalments (40-30-30% and 30-35-35%, respectively) at 0, 30 and 55 DAS [13]. The water supply established twice a day, for providing crop evapotranspiration, by drip irrigation with emitters flow rate of 8.0 L $hour^{-1}$. To minimize the effect of spontaneous vegetation, mulch of soybean applied in the density of 30 Mg ha^{-1} to 10 DAS. This information is important to ensure that the pumpkin plants used in the study suffered no water, nutritional or phytosanitary deficiencies.

The determination of the behaviour of leaf area (LA) along the growth of the plants was held at intervals of seven days, linear measurements in twenty leaves of each plant (distributed in different size classes). Thus, considered four classes of size leaves: New, small, medium and large, distributed in the terminal (new and small), central and initial regions of the branches, respectively. Also, we determined the number of leaves in each class for evaluation. The four size classes was represented as follows: New: LA ≤ 20 cm ²; small: 20 cm ² < LA < 40 cm ²; medium: 40 cm ² < LA < 60 cm ²; Large: LA ≥ 60 cm ².

Were obtained the measures of length (L) and width (W) of the leaf blade of pumpkin (Fig. 2), in which case, L defined as the distance between the point of insertion of the petiole on leaf blades and the opposite end of the leaf, whereas, W was considered as a major dimension perpendicular to the length axis [11]. For the measurements of all linear variables (L, W, T1 and T2) were used rules, scale meter and tapes. In this context, the determination of the leaf area was based on the use of simplified models estimate based only on non-destructive linear measurements, carried out the field.

For greater representation and reduce experimental errors were used 720 leaves in different sizes (new, small, medium, large). The leaves were carefully washed and dried, with subsequent realization of linear measurements (length, width, transverse T1 and T2). For the determination of leaf area leaves was used the integration device Li-color 3000 A. The regressions were performed considering the leaf area (LA) as the dependent variable and the linear measurements (L, W, T1 and T2) as independent variables [11,12]. The quantities of leaves above, 500 were used to generate mathematical models and 220 were used for subsequent validation of these models. To generate mathematical models for estimating leaf area was used the Solver optimization tool Microsoft Excel. The determination of the regression coefficients was obtained by maximizing the coefficient of determination (R^2).

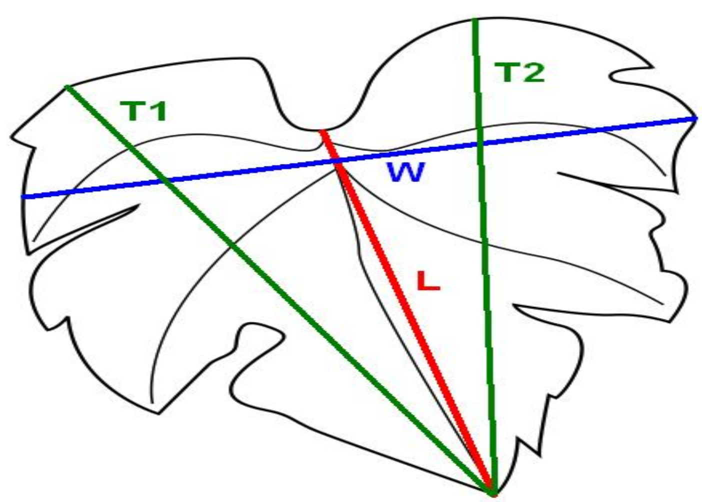

Fig. 2. Representation of linear measurements made on pumpkin leaves of the cv. menina brasileira precoce. (L: length; W: width; T1 and T2 transverse measures)

In evaluating the statistical performance indicative were employed: i) mean bean error (MBE), root mean square error (RMSE), adjustment index (d) and the index performance (c) [14]. The “c” index is obtained by the product of the correlation coefficient (r) and the rate of adjustment [12].

$$MBE = \frac{\sum_{i=1}^{N}(Pi - Oi)}{N} \quad (01)$$

$$RMSE = \left[\frac{\sum_{i=1}^{N}(Pi - Oi)^2}{N}\right]^{\frac{1}{2}} \quad (02)$$

$$d = 1 - \frac{\sum_{i=1}^{N}(Pi - Oi)^2}{\sum_{i=1}^{N}(|P'i| + |O'i|)^2} \quad (03)$$

wherein: P_i – estimated values; O_i – measured values; O_m – average of the measured values; N – number of observations; |P'i| - absolute value of the difference Pi – O_m; |O'i| - absolute value of the difference Oi – O_m.

Also performed to estimate the leaf area of pumpkin based on thermal sum accumulated or degree-days (GDD). For both, it was considered as the minimal basal (Tb) and maximal basal (TB) temperatures with values of 12 and 35°C, respectively. The sum of GDD from seeding to harvest, was given by the proposed Ometto, considering three dependent on local weather conditions cases [15].

Situation 1: $TB > TM > Tm > Tb$

$$GD = \frac{(TM - Tm)}{2} + (Tm - Tb)$$

Situation 2: $TB > TM > Tb \geq Tm$

$$GD = \frac{(TM - Tb)^2}{2\,(TM - Tm)}$$

Situation 3: $TM > TB > Tb > Tm$

$$GD = \frac{1}{2}\left(\frac{(TM - Tb)^2 - (TM - TB)^2}{(TM - Tm)}\right)$$

where:

TM = daily maximum temperature, (ºC);
Tm = daily minimum temperature, (ºC);
Tb = minimum basal temperature, (ºC);
TB = maximum basal temperature, (ºC)

3. RESULTS AND DISCUSSION

The use of non-destructive methods based on linear measurements of leaves (length and width) are being widely deployed as a good alternative to statistical prediction of leaf area performances and allows continuous assessment in the same plant [15]. In this work the real leaf area evaluated throughout the crop cycle was obtained by means of equations that allow the best practices of the leaf area of pumpkin cv. menina brasileira precoce.

In the generation and validation of equations were considered more number of leaves concentrated in small and middle class, however the coefficients of regressions were representative for all classes (Table 1). The Table 2 shows the regression coefficients and correlation models for the estimation of leaf area *Cucurbita moschata*. In regression analyzes of leaf area with the linear measures (length, width, transverse I and II) taken separately, lower values of R^2 were found when it was used only measurements of the transverse limb of the leaf (Table 2). This result was also found by Souza et al. [12] in a study on estimating leaf area of fig and by Lima et al. [16] working with leaf area of cowpea. In general, the best adjustments occurred in models that used more than a linear measure.

The model 23 [$LA = 1.9005\ (W\ T_m)^{0.7311}$] showed higher coefficient of determination (0.7212), however, its application to the estimates are necessary the measures of the width and transverse on blade. Therefore, the model 14 [$LA = 0.2720\ (L + W)^{1.8467}$] had the second highest value of R^2 (0.7164) and demand only measures the length and width, thus presenting better applicability in the field (require fewer linear measurements) and therefore was considered the best model for this situation. Souza et al. [12] and Silva et al. [11] also took into account for the choice of the mathematical model, beyond the significance of the regression and the R^2 value, the ease of obtaining data in the field of linear measurements.

Table 1. Variables statistics of the leaves to pumpkin cv. menina brasileira precoce, divided into four size classes

Description	New leaves	Small leaves	Medium leaves	Large leaves
Leaves used for generation of mathematical models				
Number of Leaves	88	220	125	66
Average leaf area (cm²)	14.54	29.64	48.80	81.63
Maximum leaf area (cm²)	19.98	39.85	59.85	130.21
Minimum leaf area (cm²)	4.69	20.05	40.13	60.26
Average length (cm)	3.99	5.34	6.71	8.83
Maximum length (cm)	8.70	10.10	9.00	11.60
Minimum length (cm)	1.90	2.50	4.00	5.80
Average width (cm)	5.46	7.43	9.42	12.22
Maximum width (cm)	11.40	13.60	11.10	16.40
Minimum width (cm)	2.50	3.40	5.60	7.50
Leaves used for validation of the mathematical models				
Number of Leaves	37	93	61	30
Average leaf area (cm²)	15.33	29.79	49.33	75.66
Maximum leaf area (cm²)	19.73	39.99	59.22	106.78
Minimum leaf area (cm²)	8.95	20.12	40.63	60.03
Average length (cm)	4.06	5.57	6.79	8.36
Maximum length (cm)	5.10	11.00	10.40	11.00
Minimum length (cm)	3.00	3.00	4.90	5.30
Average width (cm)	5.47	7.72	9.47	11.49
Maximum width (cm)	7.40	13.50	14.20	14.50
Minimum width (cm)	3.50	5.00	3.10	7.90

Fig. 3 shows the correlation between measured and estimated LA are shown and the spatial distribution of points, its application in the estimation of the LA, when correlated with the measure LA provides the lowest slope (linear equation through the origin) and the highest coefficient of determination, indicating that it tends to provide better results for the estimation of LA.

The Table 3 indicates the statistical performance of the models generated for estimation of LA, in which case, correlated the estimated LA (models of Table 2) and corrected by linear regressions with the measure LA. We adopted this procedure because the applications of the linear regressions the estimates can greatly improve the statistical performance of the simplified model to estimate LA [8].

The MBE indicative shows the mean deviation, with negative values indicating underestimation and vice versa. The RMSE is the square root of the mean squared error and informs about the actual value of the error produced by the model tested. The adjustment index "d" ranges from 0 to 1 and represents how the estimated values fit with the measured values [14]. According to Souza et al. [15] the joint use of these statistical indicators is the appropriate alternative for the validation of statistical models because it allows simultaneous analysis of deviation from the mean, identifying the occurrence of under or overestimation, scattering and adjustment of the model relative measures and the best performances of the models tested are obtained by lower absolute values of MBE and RMSE and higher values of "d".

With the above behavior for each statistical indicator, the values of each coefficient for each model were listed position, following the increasing order between best and worst performance, so the 29 models, one listed as "1" performed better and that enumerated "29" showed lower performance for each statistical indicator, so at the end, we calculated the cumulative Vp. Thus, the model 23 was reached Vp equal to 07; Model 14 was accumulated with Vp equal to 14. The model 25, with R^2 equal to 0.2138, obtained a cumulative Vp of 133 and is considered the worst model to be adopted in estimating the leaf area of this cultivar in these environmental conditions.

Table 2. Regression models and correlation coefficients to estimate the leaf area of pumpkin cv. menina brasileira precoce, based on simple linear measurements

Analytical model	Adjusted coefficients			
	a_1	a_2	b	R²
LA1) $LA = a_1 L$	6.9129	...	....	0.6065
LA2) $LA = a_1 L^b$	1.3117	...	1.7568	0.6541
LA3) $LA = a_1 W$	4.9718	...	...	0.6246
LA4) $LA = a_1 W^b$	6.9129	...	0.8607	0.5712
LA5) $LA = a_1 T_1 + a_2 T_2$	1.2656	4.0206	...	0.6203
LA6) $LA = a_1 (T_1 + T_2)$	2.5866	...	...	0.6153
LA7) $LA = a_1 (T_1 + T_2)^b$	4.4707	...	0.8143	0.5476
LA8) $LA = a_1 [(T_1 + T_2)/2]^b$	7.8840	...	0.8118	0.5465
LA9) $LA = a_1 (L W)$	0.7184	...	...	0.6790
LA10) $LA = a_1 (L W) + a_2 (L W)^2$	0.5917	0.0010		0.6096
LA11) $LA = a_1 (L + W)$	2.8974	...	...	0.6296
LA12) $LA = a_1 (L + W) + a_2 (L + W)^2$	0.4662	0.1481	...	0.7154
LA13) $LA = a_1 (L W)^b$	1.0207	...	0.9196	0.7079
LA14) $LA = a_1 (L + W)^b$	0.2720	...	1.8467	0.7164
LA15) $LA = a_1 (L T_m)$	0.7493	...	...	0.6169
LA16) $LA = a_1 (L T_m) + a_2 (L T_m)^2$	0.6201	0.0003	...	0.5935
LA17) $LA = a_1 (L + T_m)$	2.3045	...	...	0.6201
LA18) $LA = a_1 (L + T_m) + a_2 (L + T_m)^2$	0.3497	0.1374	...	0.6535
LA19) $LA = a_1 (L T_m)^b$	2.1263	...	0.6932	0.6948
LA20) $LA = a_1 (L + T_m)^b$	2.2779	...	1.1016	0.6495
LA21) $LA = a_1 (W T_m)$	0.5400	...	...	0.6689
LA22) $LA = a_1 (W + T_m)$	2.5823	...	...	0.6328
LA23) $LA = a_1 (W T_m)^b$	1.9005	...	0.7311	0.7212
LA24) $LA = a_1 (W + T_m)^b$	1.4509	...	1.1987	0.6890
LA25) $LA = a_1 (L W T_m)$	0.0668	...	...	0.2138
LA26) $LA = a_1 (L + W + T_m)$	1.8879	...	...	0.6318
LA27) $LA = a_1 (L + W + T_m) + a_2 (L + W + T_m)^2$	1.2443	0.0250	...	0.7074
LA28) $LA = a_1 (L W T_m)^b$	1.2492	...	0.5758	0.7155
LA29) $LA = a_1 (L + W + T_m)^b$	0.7303	...	1.2957	0.7073

L: leaf length, obtained through the distance between the point of insertion of the petiole and leaf blade on the opposite end of the leaf; W: leaf width, considered as the largest dimension perpendicular to the length axis; Tm: average transverse, obtained by the sum of the transverse I and II divided by 2

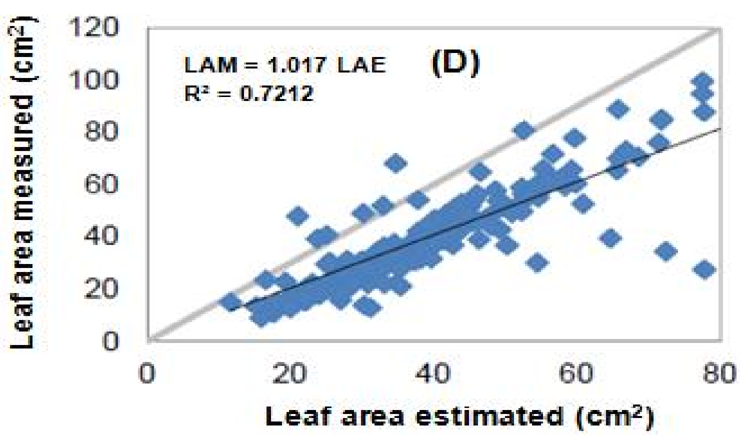

Fig. 3. Graphical representation of the distribution of points as the relationship between measured LAM and estimated LAE (cm²) to pumpkin cv. menina brasileira precoce by LA23 model

In general, it can be seen that 15 models have a tendency to underestimate the leaf area up to 3.73 cm², while 14 models overestimate the area of the leaf within 9.52 cm². In Table 3, the best model (related to MBE) was LA8 with a MBE of -0.08 cm². The RMSE indicative expresses the actual value of the error produced by the model in question and the level of the measured scattering produced, thus, the lower the value of this index the best performance of the method. In this work the values for RMSE ranged from 10.46 (LA23) to 17.59 cm² (LA25).

After application of the linear estimates by different models regressions, noted that the values adjustment (d) ranged from 0.9995 to 0.9983. This index measures the dispersion of the data, expressing the accuracy of the estimated values and actual [17]. The performance index, called "c", suffered variations from 0.85 to 0.46 and the higher the value of these indices to better performance of the mathematical model. As proposed by classification of Camargo & Sentelhas [18], to generated models with performance index "c" greater than 0.85 are classified as great. In this case the models 12, 14, 23 and 28 (which show performance values near to 85%), while for the situation 0.75<c≤0.85, the models are considered very good (22 models).

After defining the mathematical model recommended for implementation at the field level [$LA = 0.2720 (L + W)^{1.8467}$] was calculated leaf area of plants throughout the experimental period and in all seasons planting. In Fig. 4 the behavior of leaf area as a function of accumulated thermal time (around 1200 AD) is presented.

Table 3. Statistical Indicative of models to estimating the leaf area of pumpkin cv. menina brasileira precoce, based on, two and/or three linear variables

Model	MBE (cm²)	RMSE (cm²)	D	R	C	Cumulative Vp
LA1	2.72 (20)	12.47 (20)	0.9988 (23)	0.78 (24)	0.78 (24)	111
LA2	-0.69 (13)	11.79 (12)	0.9993 (10)	0.81 (12)	0.81 (12)	59
LA3	-2.47 (18)	12.14 (16)	0.9989 (20)	0.79 (18)	0.79 (18)	90
LA4	-3.73 (22)	13.11 (22)	0.9987 (25)	0.76 (26)	0.75 (26)	121
LA5	0.73 (14)	12.41 (19)	0.9988 (22)	0.79 (19)	0.79 (19)	93
LA6	1.58 (16)	12.66 (21)	0.9987 (24)	0.78 (22)	0.78 (22)	105
LA7	-0.17 (03)	13.38 (23)	0.9984 (28)	0.74 (27)	0.74 (27)	108
LA8	-0.08 (01)	13.41 (24)	0.9984 (27)	0.74 (28)	0.74 (28)	108
LA9	0.47 (11)	11.29 (09)	0.9994 (06)	0.82 (10)	0.82 (10)	46
LA10	3.48 (21)	12.36 (18)	0.9993 (11)	0.78 (23)	0.78 (23)	96
LA11	-2.65 (19)	12.07 (15)	0.9989 (21)	0.79 (17)	0.79 (17)	89
LA12	-0.40 (09)	10.63 (04)	0.9994 (04)	0.85 (04)	0.85 (04)	25
LA13	-0.37 (07)	10.78 (07)	0.9994 (05)	0.84 (05)	0.84 (05)	29
LA14	-0.36 (06)	10.62 (03)	0.9995 (01)	0.85 (02)	0.85 (02)	14
LA15	4.01 (23)	12.35 (17)	0.9993 (12)	0.79 (21)	0.78 (21)	94
LA16	9.07 (27)	14.59 (26)	0.9991 (15)	0.77 (25)	0.77 (25)	118
LA17	8.42 (25)	15.97 (28)	0.9983 (29)	0.79 (20)	0.79 (20)	122
LA18	8.44 (26)	14.03 (25)	0.9991 (14)	0.81 (13)	0.81 (13)	91
LA19	9.35 (28)	15.26 (27)	0.9987 (26)	0.83 (08)	0.83 (08)	97
LA20	-0.46 (10)	11.75 (11)	0.9990 (16)	0.81 (14)	0.81 (14)	65
LA21	4.23 (24)	11.69 (10)	0.9994 (07)	0.82 (11)	0.82 (11)	63
LA22	-1.22 (15)	11.99 (13)	0.9989 (18)	0.80 (15)	0.79 (15)	76
LA23	0.12 (02)	10.46 (01)	0.9994 (02)	0.85 (01)	0.85 (01)	7
LA24	-0.31 (05)	11.07 (08)	0.9991 (13)	0.83 (09)	0.83 (09)	44
LA25	9.52 (29)	17.59 (29)	0.9990 (17)	0.46 (29)	0.46 (29)	133
LA26	-1.80 (17)	11.99 (14)	0.9989 (19)	0.79 (16)	0.79 (16)	82
LA27	-0.39 (08)	10.71 (06)	0.9993 (08)	0.84 (06)	0.84 (06)	34
LA28	0.24 (04)	10.55 (02)	0.9994 (03)	0.85 (03)	0.85 (03)	15
LA29	-0.67 (12)	10.70 (05)	0.9993 (09)	0.84 (07)	0.84 (07)	40

MBE: means bias error; RMSE: root mean square error; d: adjustament index; r: correlation coefficient; c: performance index

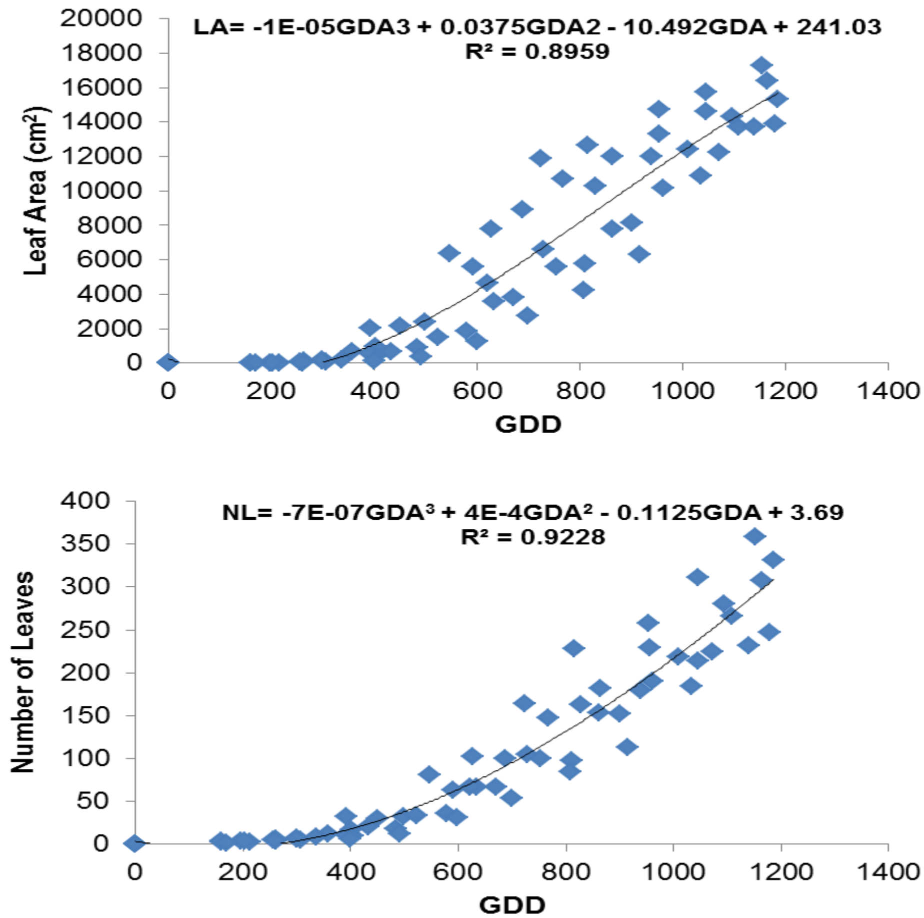

Fig. 4. Evolution of leaf area (LA) of pumpkin cv. menina brasileira precoce based to degree-days (GDD) in the region of sinop, mato grosso state, Brazil

In the study period, the rate of growth of the shoots were differentiated behaviors, characterized as exponential growth. At the beginning of the cycle, until around 300 AD group, the shoot grew very slowly, with almost constant leaf area. According Floss [19], this behavior is expected because the initial growth phase of the plant directs much of assimilates for their establishment, especially in the formation of the root system, so that it can ensure fixation and supply for water and nutrients. Subsequently, the rate of shoot growth begins to rise due to the increase in the number of leaves issued for the same thermal sum.

From 1000 the GDA can note a decreasing trend of the behavior of leaf area due to the change of the allocation of assimilates to the reproductive system curve. According Floss [19] after the plant has been reproduced and initiate senescence stage, their growth rate begins to decline until a moment that ceases. One hypothesis for this behavior is that after the reproduction phase, most of the photoassimilates is directed flowers and fruits of pumpkin (drains) and no more growth and leaf formation [19,20].

Therefore, the behavior of leaf area as a function of cumulative thermal time, it is indicated that the higher growth rate of leaf area occurs after the onset of fruiting and harvest, corroborating the results obtained by Braga et al. [20] for other cucurbits. Thus, the behavior trend of the leaf area of *Cucurbita moschata* in relation to degree-day values can be expressed by polynomials of third order, which indicate that the maximum values of LA would be 43537.6 cm^2 when the accumulation occurs in 1824.7 GDD. However, depending on local climatic conditions, particularly the rainfall regime of the study period, the above accumulations were not observed. According Floss [19], uses the equations of linear or quadratic regressions corrects the fluctuations of time and makes it possible to evaluate the growth trend of a certain crop.

4. CONCLUSION

The leaf area of pumpkin (*Cucurbita moschata* Duch) cv. Menina Brasileira Precoce, cultivated field can be predicted on the basis of length (L) and width (W) of the leaf by the following equation: $LA = 0.2720 (L + W)^{1.8467}$, which in turn, was precise, simple, easy and practical to predict this important agronomic variable.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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