Forest Chemicals Revew
www.forestchemicalsreview.com
ISSN: 1520-0191
July-August 2021 Page No. 1162-1176
Article History: Received: 12 May 2021 Revised: 25 June 2021 Accepted: 22 July 2021 Publication: 31 August 2021

Prediction of Leaf Area Using Montgomery Models in Ramie

Hailin Wei[1,2], Yingping Deng[2], Zhaozhong Chen[2], Xiaohui Wang[2], Xumeng Li[2,*]
[1]Hunan Academy of Forestry, Hunan, China
[2]Hunan Agricultural University, Changsha, 410128, Hunan, China
*Corresponding Author.

Abstract:

The Montgomery model has been proved to be suitable for the leaf area estimation, that is, $A = cm1 \times L \times W$. However, the same plant affected by different genes causes the variation of leaf shape. The effects of allometric growth and variation of ramie leaf on the parameter (cm1) of Montgomery model still needs further exploration. In this study, a total of 3020 leaves were taken from 151 varieties in the ramie germplasm resource nursery (20 leaves/variety). Based on the root mean square error (RMSE) and the parameter (cm1) variation coefficient, six mathematical models of leaf area were compared. The results show that the Montgomery model is the optimum support model. It is also found that the parameter (cm1) of Montgomery model of ramie leaf with different genes varies greatly, which ranges from 0.5633~0.6621; the morphological variation of ramie leaf can be described by the change in oval parameters (a, b, c) and the length of leaf opex, and partially explain the change in the parameters of Montgomery mod-el. Therefore, in order to improve the accuracy of leaf area estimation of Montgomery model, the allometric growth and variation of ramie leaf with different genes should be considered.

Keywords: *Ramie, Montgomery model, Leaf area estimation, Allometric growth, Morphological variation.*

I. INTRODUCTION

As proposed as a similarity principle of organism [1], the area and weight of an organism are respectively proportional to the square of its length (the area–length allometry), and the 3/2 power of its surface area (the weight–area allometry) at a constant density. Actually in the estimation of biological data, the allometric growth indicators of the area-length and weight-area relationships of an organism is close but not exactly equal to 2 and 3/2. For example, the allometric growth relationship among the surface area, length, and weight of six fish varieties indicated wide estimate ranges for their allometric growth indicators from 1.88~2.22 and

Forest Chemicals Revew
www.forestchemicalsreview.com
ISSN: 1520-0191
July-August 2021 Page No. 1162-1176
Article History: Received: 12 May 2021 Revised: 25 June 2021 Accepted: 22 July 2021 Publication: 31 August 2021

1.54~1.69, respectively [2]. The main reason is that organisms vary greatly in the area-length and weight-area allometric growth indicators, and for the same organism, they could be affected by different genes and environmental factors [3]. The leaf is an important organ for the transpiration, photosynthesis and heat balance [4]. The leaf area, weight, thickness, and leaf mass per unit area are significant functional indicators [5,6]. These indicators are affected by genes, environments, and agronomic practice or management [7-9]. At the same time, they reflect the growth status of plants that affect plant growth rate, fruit development quality and harvest yield [10-13]. Therefore, functional indicators of these leaves are widely used in physiological and ecological researches.

The leaf area, an important parameter of plant canopy, has significant influence on the light interception and penetration, leaf energy balance and solar radiation distribution. In order to quickly and easily estimate the functional indicators, such as leaf area and dry weight, the relationship model between the functional indicators of leaf has been investigated [14-20]. Montgomery proposed a formula for the leaf area (A) of the corn (herein after referred to as Montgomery Model) as: $A = c \times L \times W$, where c is a fitting constant; L is leaf length and W is leaf width [21,22]. Subsequently, Montgomery Model was proved to be also suitable for the calculation of leaf area, such as, rice and sorghum [23,24]. Therefore, this model has been widely used in leaf area estimation for field crops. Peijian Shi based on the leaf morphology of six plant groups, Montgomery Model was validated, and used to estimate the ratio range of the leaf area to the product of leaf length and width: $(1/2, \pi/4)$[25].

The ratio mentioned above varies among plants within a population. At the same time, the ratios for the same plant species are also largely affected by genes and environmental factors [26,27]. However, only very limited information is available about the relationship between the leaf indicators. Therefore, 151 ramie varieties were sampled as a representative germplasm collection and used to determine the relationship among the ramie leaf area, length and width. The change range of parameters of Montgomery Model of ramie leaf with different gene types was explored, and explained from the morphological variation.

II. MATERIALS AND METHODS

2.1. Plant Materials

The plants were collected from the ramie germplasm resource nursery in this study. The nursery is located at the Yunyuan Teaching Base of Hunan Agricultural University, Changsha, China (N28°11′01.981", E113°04′10.159"), with humid subtropical monsoon climate. With abundant rainfall, good light and heat conditions, ramie grows well in the nursery. A total of 151

Forest Chemicals Revew
www.forestchemicalsreview.com
ISSN: 1520-0191
July-August 2021 Page No. 1162-1176
Article History: Received: 12 May 2021 Revised: 25 June 2021 Accepted: 22 July 2021 Publication: 31 August 2021

ramie varieties, including Huazhu No. 4, Manyuanzuan and Niu'erqing, were sampled to represent the ramie germplasm collection, all of which were transplanted on January 16, 2018. The field trial was divided into six blocks, each with 26 plots (each with a ramie variety). The planting map for the germplasm resource was shown in Appendices Table S1.

2.2. Data Collection

One week before the second-season ramie harvest, 10 ramie plants were randomly selected from each variety, and the 5th and 6th real leaves from the top of each plant were collected with a total of 20 leaves. The leaf image was taken in a dark box, and the image processing method was then used to obtain leaf data. The operation details are as follows: (1) The Photoshop software is used to preprocess the images and obtain leaf information. (2) After converted into a binary image in MATLAB.2016, leaf tip and petiole are marked by human-computer interaction; specifically, the mouse is used to mark the leaf tip, searching for the petiole based on the maximum distance measurement, and rotating the image to make the leaf tip straight down based on the direction of leaf tip-petiole segment. (3) The toolbox regionprops in MATLAB is used to obtain the leaf area, length and width (the smallest rectangle on the periphery). (4) The leaf information data obtained by the image recognition processing are all in pixel, and the leaf length, width and area are calculated in accordance with the pixel value represented by each centimeter.

2.3. Statistical Analysis

Models 1-6 were used for fitting the data of leaf area (Table I). In Model 1 (Montgomery model）, it is assumed that the leaf area is proportional to the rectangle area (leaf length and width are its two sides). For the simplicity, the parameter (cm1) in the Model 1 was called the Montgomery parameter. In Model 2, plane projection was used to reveal the proportional relationship between leaf and rectangle areas. Models 3 and 4 represent the relationship among the leaf area, length and width respectively. In Models 5 and 6, it was assumed that the leaf area is proportional to the squares of leaf length and width respectively, which was proposed by Thompson's similarity principle.

Table I. Six equation measurement models for leaf area

No.	Model type	No.	Model type
Model 1	$A=c_{m1}(L\times W)$	Model 4	$A=c_{m4}W^{bm4}$
Model 2	$A=c_{m2}(L\times W)^{bm2}$	Model 5	$A=c_{m5}L^{2}$

Forest Chemicals Revew
www.forestchemicalsreview.com
ISSN: 1520-0191
July-August 2021 Page No. 1162-1176
Article History: Received: 12 May 2021 Revised: 25 June 2021 Accepted: 22 July 2021 Publication: 31 August 2021

Model 3	$A=c_{m3}\,L^{bm3}$	Model 6	$A=c_{m6}W^2$

In Model 1, c_{m1}=exp(a1); the exponential constant and intercept in other models also have a similar relationship; A =leaf area; L =leaf length; W=leaf width; Wt = leaf weight; and other symbols are the parameters to be input.

The goodness-of-fit of model was measured by the following equation:

$$\mathrm{RMSE} = \sqrt{\sum_{i=1}^{n}(\mathrm{OBS_i} - \mathrm{SIM_i})^2/n} \qquad (1)$$

In equation (1) $\mathrm{OBS_i}$ is the leaf area; i is the i-th leaf; $\mathrm{SIM_i}$is the estimated value of model.

The standard deviation coefficient (Vσ) was used to measure the dispersion of data.

$$V_\sigma(x) = \frac{\sigma}{\bar{x}} \qquad (2)$$

In equation (2) σ is standard deviation; $\bar{x}$ is mean.

The effectiveness of leaf area estimation [28] was evaluated by the cross-validation. Two sampling methods were used. One was to randomly sample varieties, then the leaves of the selected varieties were taken as samples (random varieties sampling). The other was to randomly sample leaf samples from all the 151X20 leaves (random leaf sampling). The sampled leaves were divided into two parts. One part（leaves of 1-150 varieties sampled by varieties sampling or（1-150）X20 leaves sampled by leaf sampling）was randomly selected and kept as the data for model validation, and other samples were used for the pre-test. The cross-validation was repeated 10,000 times, and the RMSE was used as the final estimation effect.

Forest Chemicals Revew
www.forestchemicalsreview.com
ISSN: 1520-0191
July-August 2021 Page No. 1162-1176
Article History: Received: 12 May 2021 Revised: 25 June 2021 Accepted: 22 July 2021 Publication: 31 August 2021

III. RESULTS

3.1. Goodness-of-fit of Area Model

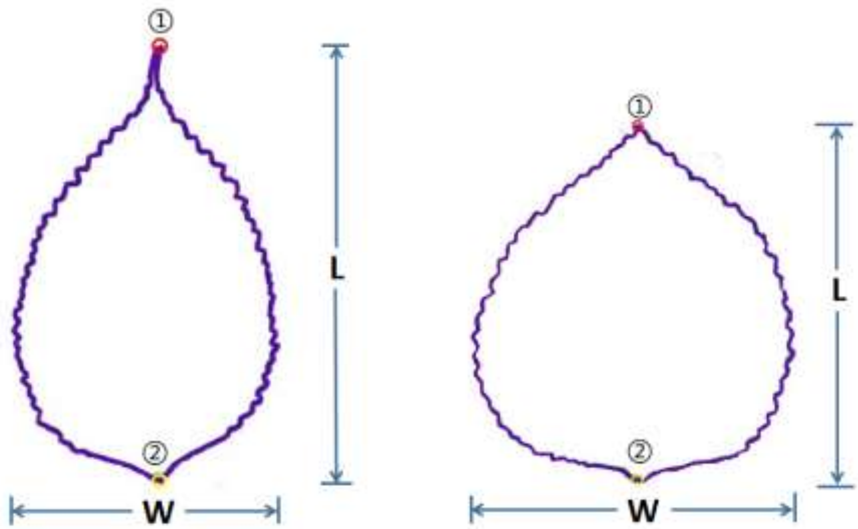


Fig 1: Schematic diagram of the ramie leaf morphological indicators

"L" is denoted leaf length; "W" is denoted leaf wide; the area of purple border is the leaf area; circle ① is denoted leaf opex; circle ② is denoted leaf basis point.

The morphological indicators of ramie leaves are shown in Figure 1. The data of all varieties were taken to test the overall fitting model (Figure 2). The RMSEs estimated for six models in order are 5.06, 5.01, 13.23, 7.64, 14.18, and 8.86. The goodness-of-fits for Models 3-6 are obviously worse than those of Models 1 and 2 (Model 2> Model 1; Model 4 > Model 3; Model 6 > Model 5).

Forest Chemicals Revew
www.forestchemicalsreview.com
ISSN: 1520-0191
July-August 2021 Page No. 1162-1176
Article History: Received: 12 May 2021 Revised: 25 June 2021 Accepted: 22 July 2021 Publication: 31 August 2021

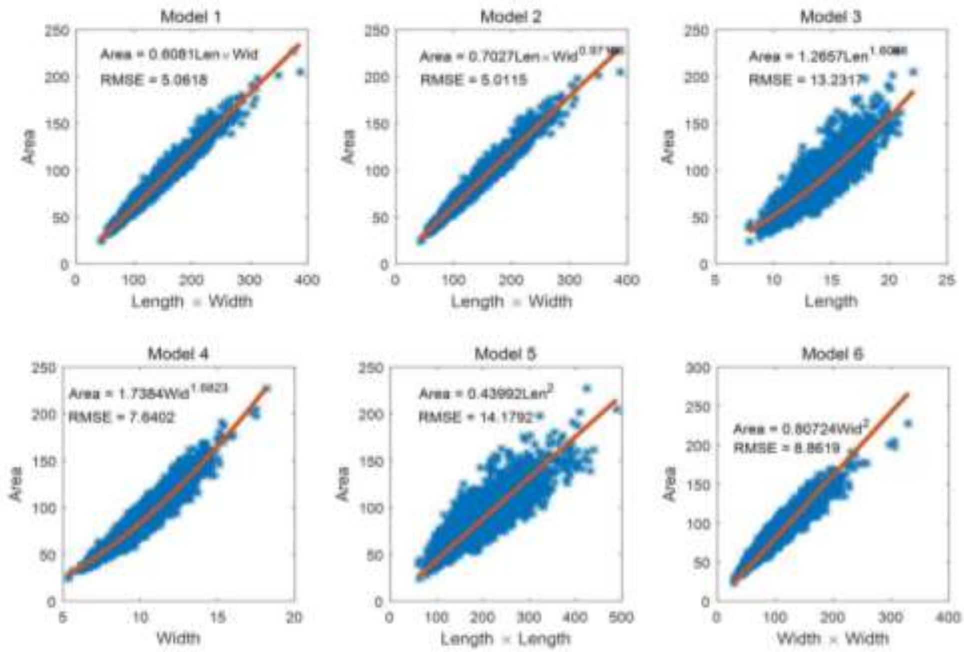


Fig 2: Overall fitting model based on the leaf data of all varieties

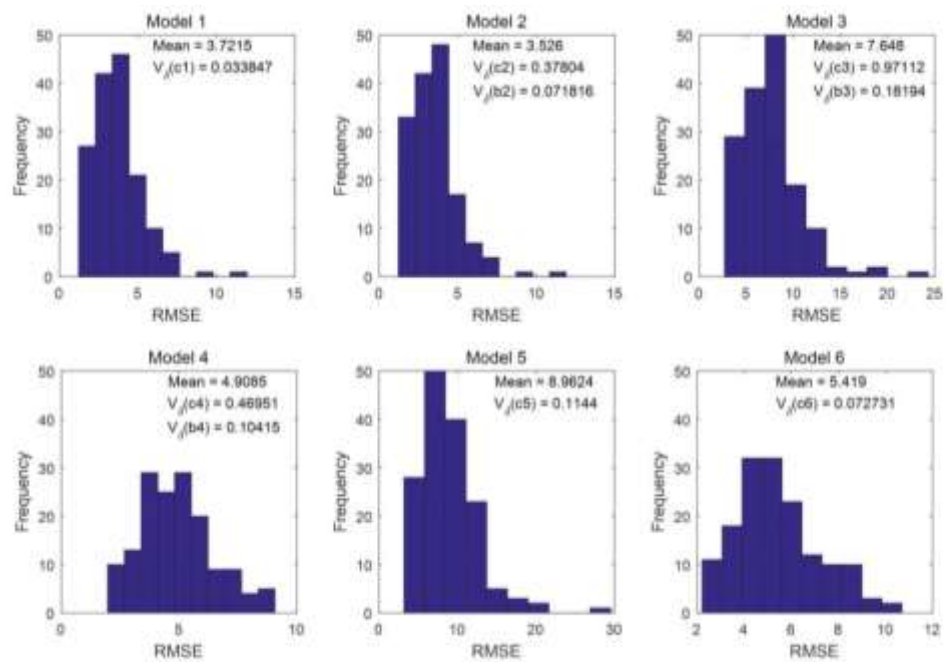


Fig 3: Frequency histogram of RMSE of model fitting for each variety.
"Mean"is denoted mean of the RMSE,"Vδ"is denoted standard-deviation of the parameter of model fitting for each variety.

ISSN: 1520-0191
July-August 2021 Page No. 1162-1176
Article History: Received: 12 May 2021 Revised: 25 June 2021 Accepted: 22 July 2021 Publication: 31 August 2021

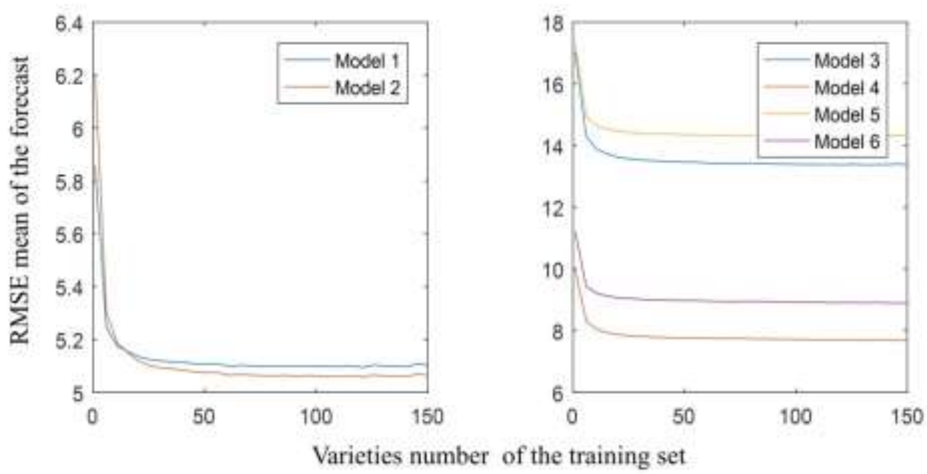
The model was fitted with the data based on the classification of 151 ramie varieties. The frequency distribution of RMSEs and the corresponding means in Fig 3 show that the goodness-of-fit based on the classification of varieties is similar to the overall goodness-of-fit based on the data of all varieties, that is, the goodness-of-fits of Models 3-6 are obviously inferior to those of Models 1 and 2, of which Model 2> Model 1; Model 4 > Model 3; Model 6 > Model 5.

3.2 Parameter Consistency of Area Model

According to the classification of varieties, the leaf area data were used to fit the model. The standard deviation coefficients of the fitted parameters (c_m and b_m) in Fig 3 show that the parameters (c_m and b_m) consistency of Models 1-6 is ordered not the same as the goodness-of-fit (Model 1> Model 2; Model 4 > Model 3; Model 6 > Model 5).

3.3 Cross-Check of Area Model

The leaf samples were divided into the training and testing sets for cross-check of area model. In the training and testing set, two sampling methods were used: variety sampling and leaf sampling. The variety sampling is to randomly select some from 151 varieties, and all the selected varieties are used as the training set. The leaf sampling is to randomly select some from all samples (3020 leaves) as the training set.



Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
July-August 2021 Page No. 1162-1176
Article History: Received: 12 May 2021 Revised: 25 June 2021 Accepted: 22 July 2021 Publication: 31 August 2021

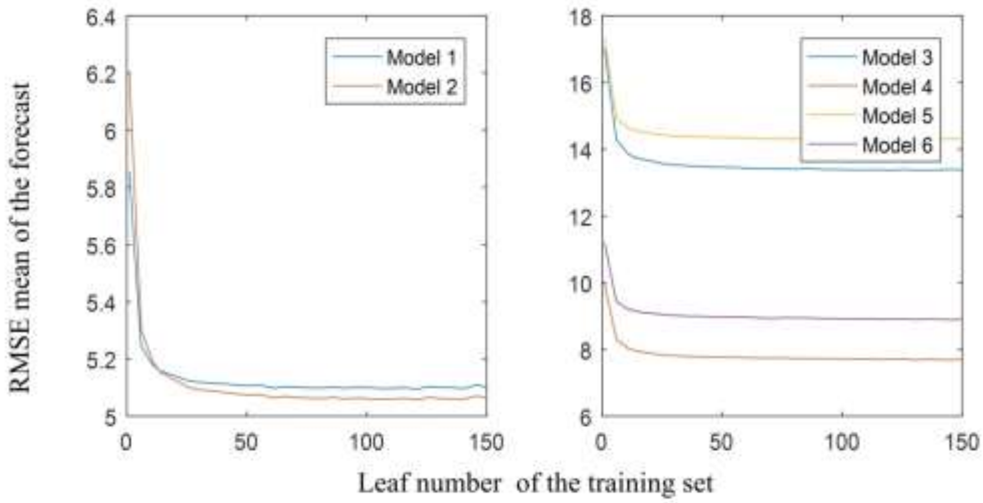


Fig 4: Cross-check of area model by sampling varieties and by sampling leaf samples

As shown in Fig 4, random variety sampling and random leaf sampling show that the prediction error（RMSE）is related to the capacity of training set in the model test, and becomes smaller with the increase of sample size (number of varieties), that is, the predictive ability of model depends on the capacity of training set; when the training set more than 280 leaves, the result is opposite, that is, the prediction effect of Model 2 is slightly better than that of Model 1. When sample size (the number of varieties) is big enough (n>280), based on the random variety sampling, the prediction effects of models were ranked as follows: Model 1>Model 2>Model 5>Model 3>Model 6>Model4.

IV. DISCUSSION

4.1 Selection of Leaf Area Model

The Montgomery model has been proven effective in predicting the leaf area of many crops [23,24]. In fact, Fig 3 confirmed that the variation coefficient of parameters (c and b) of Montgomery model is indeed very small, and the relative prediction error of Model 1 is about 3%. Therefore, the Montgomery model can be used for predicting the leaf area of ramie. Fig 3 indicates that Model 1 has more consistent fitting parameters than Model 2. At the same time, for the 99.7% confidence interval of proportion indicator, Model 2 includes Model 1. Therefore, according to standard [29], Model 1 can be used to replace Model 2. The predictive ability of a model depends on its structure and the sample size in the training set. The resampling in this paper also confirmed this. The larger the sample size in the training set, the better the prediction ability; When the sample size (the number of leaf) is big enough (n is more than 90), the Model 2 is better.

Forest Chemicals Revew
www.forestchemicalsreview.com
ISSN: 1520-0191
July-August 2021 Page No. 1162-1176
Article History: Received: 12 May 2021 Revised: 25 June 2021 Accepted: 22 July 2021 Publication: 31 August 2021

4.2 Effect of Leaf Variation on the Model

The effect of morphological variation in leaf area on Montgomery model is rarely discussed. If the leaf morphology conforms with the principle of similarity, the leaf length and leaf area will be proportional to leaf width and the product of leaf length and width respectively. Conversely, if the relationship between the leaf area and the product of leaf length and width changes, the leaf morphology will not conform to the principle of similarity. Classified by varieties, to fit Montgomery model, 95% confidence interval of the parameters were (0.5674, 0.6498). The mean for the interval length is 13.54%, ranging from 0.5633 to 0.6621. And the difference between the two is 16.23% of the mean. Therefore, it is concluded that the relationship between the leaf area and the product of leaf length and width does not strictly conform to the principle of similarity, which is not strictly valid. Goodness-of-fits indicate the following order (from the best to worst): Models 5, 3, 6 and 4. Models 5 and 3 are generally better than Models 6 and 4, that is, the leaf width as a factor can better explain the leaf area than the leaf length.

The shape of ramie leaf is close to the oval. The lower end is nearly semicircular, and the upper end is nearly parabolic, as shown in the following formula (3).

$$\begin{cases} \frac{x^2}{a^2} + \frac{y}{b} = 1 & y > 0 \\ \frac{x^2}{a^2} + \frac{y^2}{c^2} = 1 & y \leq 0 \end{cases} \tag{3}$$

Its area is as follows:

$$S = 2\int_0^b a\sqrt{1-\frac{y}{b}}\,dy + 2\int_0^b a\sqrt{1-\frac{y^2}{c^2}}\,dy = \frac{2}{3}ab + \frac{\pi}{4}ac \tag{4}$$

In equation (4) S is leaf area; a is leaf width; b+c is the leaf length.

ISSN: 1520-0191
July-August 2021 Page No. 1162-1176
Article History: Received: 12 May 2021 Revised: 25 June 2021 Accepted: 22 July 2021 Publication: 31 August 2021

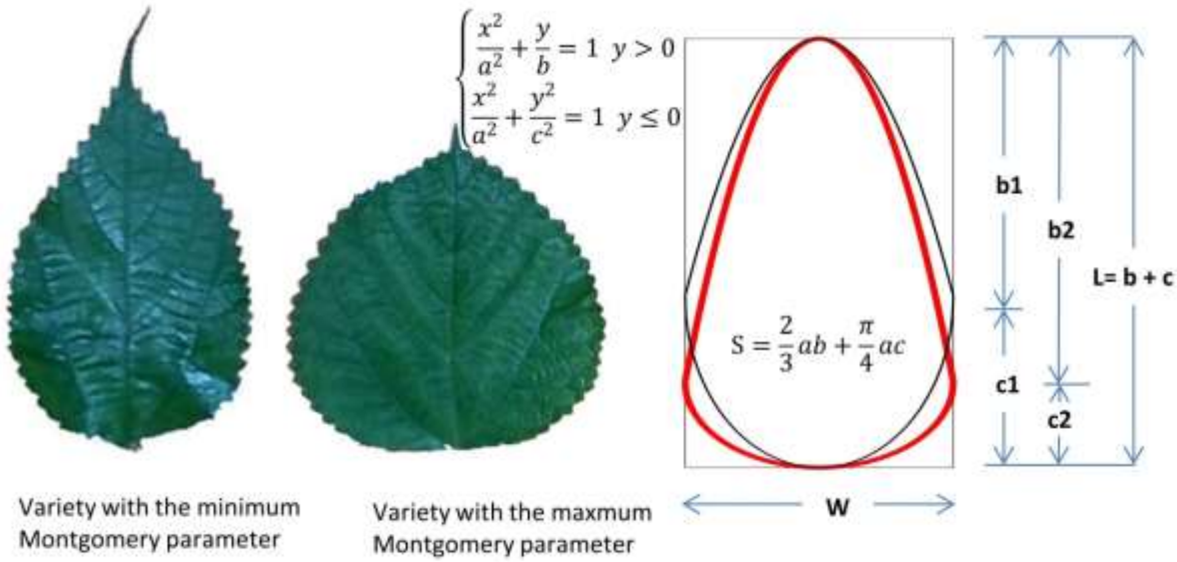


Fig 5: Morphological variation of ramie leaf

The oval area is 0.666< S <0.785. When c = 0, the oval is parabolic, and its area S is 0.667×L×W; when b = 0, the oval is parabolic, and its area S is 0.785×L×W. The coefficient of leaf area S is affected by the ratio of oval parameters b to c. The smaller the b:c, the larger the coefficient of area S; when the length and width of oval leaf are equal, the smaller the b:c, the larger the area S. However, it is found that the parameters of the fitted Montgomery model range from 0.5633 to 0.6621, which is smaller than the lower bound value (0.666) of coefficient of oval area S. The main reason is that the leaf shape of ramie has long and thin leaf opex, which is difference in the length for different varieties (Fig 4). There are variations in the leaves of different varieties. Therefore, the differences of varieties should be taken into consideration, and the leaves of different varieties should be taken to collect data for the establishment of a unified model.

It is assumed that when the oval is semicircular, the leaf area (S)=0.667×L×W (i.e.b=0); in the Montgomery model 1 (S=cm1×L×W), cm1=0.667; When the oval is parabolic, the leaf area (S)=0.785×L×W (i.e.b=0); in the Montgomery model 1 (S=cm1×L×W), cm1 = 0.785. As we can see, the size of cm1 is affected by b and c. The smaller b:c, the larger cm1; when the leaf length (L) and leaf width (W) are equal, the smaller b: c, the larger the area (s). We know that the value range of cm1 is (0.5633,0.6621), in which the maximum value is less than the lower bound of the ovate area formula coefficient of 0.667. The main reason is that ramie has long and thin leaf opex, and the length of whiskers of various varieties is different (Fig 5). There are variations in the leaves of different varieties. Therefore, the differences of varieties should be taken into consideration, and the leaves of different varieties should be taken to collect data for the establishment of a unified model.

V. CONCLUSIONS

This study has proved that Montgomery model is suitable for estimating the leaf area in ramie by using the leaf length and width; the Montgomery parameter (cm1) is estimated to be 0.6081, and its 95% confidence interval is (0.5633, 0.6621). Different varieties of plants have different ratio coefficients of the leaf area to the product of leaf length and width. The same plant is also different due to the regulation of gene mutation and environmental factors. It is found that there are two reasons for the leaf variation among varieties of ramie; one is the change of oval parameters (a, b, c), and the other is the change in length of leaf opex, which affects the Montgomery parameter (cm1) values. In order to establish a model suitable for the area estimation across varieties is established, leaves from a diverse panel of germplasm should be investigated as in this study.

This paper verified the effectiveness of Montgomery model for rapid leaf area measurement, put forward strategies to improve the accuracy of estimation model, and explained the reasons for the differences in parameters of different varieties of leaf area estimation model. In future studies, we can further use Montgomery parameter to estimate leaf area to explore the classification of varieties, and then carry out the association of leaf shape associated genome. In addition, it is also Interesting and valuable research to improve the oval function used in this paper for the simulation and visualization of leaf shape.

ACKNOWLEDGEMENT

This study was supported by Key Research and Development Program of Hunan Province (2022NK2047, 2020NK2025) and Major Research Project of Academic Degree and Postgraduate Education Reform in Hunan Province ([2019] No.293-164).

Supplementary Materials: Table S1: Planting map for the germplasm resource.

Author Contributions: Data curation, Wei, H. and Deng, Y.; project administration, Wei, H. and Chen, Z.; writing—review and editing, Wei, H. and Deng, Y.; investigation, Li, X., Chen, X. and Wang, X.; supervision and visualization, Li, X. and Wang, X.; conceptualization, funding acquisition, writing—original draft preparation and resource, Wei, H.; software and validation, Deng, Y.; methodology, Chen, Z. All authors have read and agreed to the published version of the manuscript.

Data Availability Statement: The data can be found in the online supplementary tables of this manuscript.

Conflicts of Interest: The authors declare no conflict of interest.

REFERENCES

[1] Thompson, Wentworth D (1943) On growth and form. New Edition. Journal of Nervous & Mental Disease 98(5): 558
[2] O'Shea B, Mordue-Luntz AJ, Fryer RJ, Pert CC, Bricknell IR (2006) Determination of the surface area of a fish. Journal of Fish Diseases 29(7): 437-440
[3] Wei H, Li X, Li M, Huang H (2019) Leaf shape simulation of castor bean and its application in nondestructive leaf area estimation. International Journal of Agricultural and Biological Engineering 12(4): 135-140
[4] Goudriaan J, Laar (1994) Modelling potential crop growth processes: textbook with exercises. Springer Netherlands.
[5] Sha P, Chao L, Zhang W, Su X, Wang N, Li Y, Jing G, Yang W, Wang G, Ive DS (2013) The scaling relationships between leaf mass and leaf area of vascular plant species change with altitude. PLOS ONE. 8:e76872. doi: 10.1371/journal.pone.0076872
[6] Niklas KJ, and Christianson ML (2011) Differences in the scaling of area and mass of Ginkgo biloba (Ginkgoaceae) leaves and their relevance to the study of specific leaf area. Am. J. Bot. 98: 1381–1386. doi: 10.3732/ajb.1100106
[7] Zhao C, Chen L, Ma F, Yao B, Liu J (2008) Altitudinal differences in the leaf fitness of juvenile and mature alpine spruce trees (Picea crassifolia). Tree Physiology 2008(1): 133-141
[8] Farris MA (1984) Leaf size and shape variation associated with drought stress in Rumex acetosella L. (Polygonaceae). American Midland Naturalist 111(2): 358-363
[9] Iwata H, Nesumi H, Ninomiya S, Takano Y (2002) Ukaiet, Y. Diallel analysis of leaf shape variations of citrus varieties based on elliptic fourier descriptors. Breeding Science 52(2): 89-94
[10] Fownes H. (1995) Phosphorus limitation of forest leaf area and net primary production on a highly weathered soil. Biogeochemistry 29(3): 223-235
[11] Suzuki A, Shimizu T, Aoba K (2008) Effects of leaf/fruit ratio and pollen density on highbush blueberry fruit quality and maturation. Engei Gakkai Zasshi 67(5): 739-743
[12] Peksen E (2007) Non-destructive leaf area estimation model for faba bean (Vicia faba L.). Scientia Horticulturae 113(4): 322-328
[13] Montero FJ, Juan J, Cuesta A, Brasa A (2000) Nondestructive methods to estimate leaf area in vitis vinifera L. Hortscience A Publication of the American Society for Horticultural Science 35(4): 696-698.
[14] Borghezan M, Gavioli O, Pit FA, Silva A (2010) Mathematical models for leaf area estimative of the grapevine cultivars (Vitis vinifera L.). Ciência E Técnica Vitivinícola 25(1): 1-7

[15] Wachs JP, Stern HI, Burks T, Alchanatis V (2010) Low and high-level visual feature-based apple detection from multi-modal images. Precision Agriculture 11(6): 717-735

[16] Francisco JP, Diotto AV, Folegatti MV, Silva LDDB, Piedade SMS (2014) Leaf area estimative of pineapple (cv. Vitoria) using allometric relationships. Revista Brasileira De Fruticultura 36(2): 285-293.

[17] Shi P, Yu K, Niklas KJ, Schrader J, Song Y, Zhu R, Li Y, Wei H, Ratkowsky DA (2021) A General Model for Describing the Ovate Leaf Shape. Symmetry 13: 1524. https://doi.org/10.3390/sym13081524.

[18] Lueling N, Reiser D, Griepentrog HW (2021) Volume and leaf area calculation of cabbage with a neural network-based instance segmentation.

[19] Don YU, Feng T, Yixin LI, Ren H (2019). Research and implementation of living leaf area measurement based on plant image. Intelligent Computer and Applications.

[20] Reddy S, Varma G, Davuluri RL (2021) Optimized convolutional neural network model for plant species identification from leaf images using computer vision. International Journal of Speech Technology 1-28

[21] Montgomery EG (1911) Correlation studies in corn. In: Annual Report no. 24. Agricultural Experimental Station, Lincoln, NB 1911: 108–159

[22] Shi P, Xiao Z, David R, Yang L, Ping W, Cheng L (2018) A simple method for measuring the bilateral symmetry of leaves. Symmetry 10(4): 118

[23] Jani TC, Misra DK (1966) Leaf area estimation by linear measurements in Ricinus communis. Nature 212: 741–742.

[24] Palaniswamy KM, Gomez KA (1974) Length-width method for estimating leaf area of rice. Agron J 66: 430–433. https://doi.org/10.2134/agronj1974.00021962006600030027x

[25] Shi P, Liu M, Ratkowsky DA, Gielis J, Su J, Yu X, Wang P, Zhang L, Lin Z, Schrader J (2019) Leaf area-length allometry and its implications in leaf shape evolution. Trees. https://doi.org/10.1007/s00468-019-01843-4

[26] Lin S, Shao L, Hui C, Song Y, Reddy GVP, Gielis J, Li F, Ding Y, Wei Q, Shi P. Why does not the leaf weight-area allometry of bamboos follow the 3/2-power law? Front Plant Sci 9: 583. https: //doi.org/10.3389/fpls.2018.00583

[27] Griffith DM, Quigley KM, Anderson TM (2016) Leaf thickness controls variation in leaf mass per area (LMA) among grazing-adapted grasses in Serengeti. Oecologia 181(4): 1035-1040

[28] Wiens TS, Dale BC, Boyce MS, Kershaw GP (2008) Three way k-fold cross-validation of resource selection functions. Ecological Modelling 212(3-4): 244-255

[29] Shi P, Ratkowsky DA, Wang N, Li Y, Zhao L, Reddy Gadi VP, Liet BL (2017) Comparison of five methods for parameter estimation under Taylor's power law. Ecological Complexity 32(PT.A): 121-130

Forest Chemicals Revew
www.forestchemicalsreview.com
ISSN: 1520-0191
July-August 2021 Page No. 1162-1176
Article History: Received: 12 May 2021 Revised: 25 June 2021 Accepted: 22 July 2021 Publication: 31 August 2021

Appendices

Table S1. The planting map for the germplasm resource

<table>
<tr><td rowspan="22">Ramie nursery</td><td>/</td><td>/</td><td>8-3101</td><td>Huangjinma</td><td>83-193</td><td>Yema</td><td rowspan="22">Cement road</td></tr>
<tr><td>Xiaoyelugan</td><td>Ganzhu 4</td><td>Xinyuma</td><td>Q5</td><td>Niuerqing</td><td>Gaoanma</td></tr>
<tr><td>Tongpiqing</td><td>Manyuanzuan</td><td>Ganzhu 3</td><td>3-11</td><td>2-19</td><td>2-12</td></tr>
<tr><td>Zhongyixuexiao</td><td>3-37</td><td>2-7</td><td>3-10</td><td>7-8</td><td>7-15</td></tr>
<tr><td>1-33</td><td>4-7</td><td>1-3</td><td>7-5</td><td>2-21</td><td>1-15</td></tr>
<tr><td>3-42</td><td>Xiangzhu 3</td><td>1-16</td><td>6-35</td><td>3-40</td><td>4-3</td></tr>
<tr><td>Zhongsizhu 1</td><td>2-41</td><td>3-1</td><td>3-26</td><td>2-16</td><td>2-23</td></tr>
<tr><td>2-26</td><td>3-2</td><td>1-28</td><td>1-9</td><td>2-13</td><td>1-24</td></tr>
<tr><td>3-32</td><td>9-2</td><td>2-2</td><td>Huazhu 5</td><td>2-35</td><td>3-8</td></tr>
<tr><td>1-36</td><td>1-37</td><td>2-1</td><td>Xinzeng 1</td><td>4-9</td><td>3-25</td></tr>
<tr><td>2-10</td><td>Chuanzhu 8</td><td>3-30</td><td>1-7</td><td>3-20</td><td>4-4</td></tr>
<tr><td>3-34</td><td>Huazhu 4</td><td>4-2</td><td>1-35</td><td>2-37</td><td>1-32</td></tr>
<tr><td>2-30</td><td>2-14</td><td>2-3</td><td>3-6</td><td>3-35</td><td>3-4</td></tr>
<tr><td>4-8</td><td>1-18</td><td>3-31</td><td>1-23</td><td>2-34</td><td>3-23</td></tr>
<tr><td>3-41</td><td>1-8</td><td>2-29</td><td>3-9</td><td>3-29</td><td>1-13</td></tr>
<tr><td>1-14</td><td>3-33</td><td>3-28</td><td>2-32</td><td>3-19</td><td>2-38</td></tr>
<tr><td>3-21</td><td>1-22</td><td>3-3</td><td>3-24</td><td>1-29</td><td>/</td></tr>
<tr><td>2-20</td><td>3-38</td><td>3-5</td><td>Xiang 7</td><td>3-22</td><td>1-5</td></tr>
<tr><td>1-41</td><td>3-16</td><td>9-35</td><td>1-11</td><td>2-17</td><td>1-25</td></tr>
<tr><td>3-39</td><td>3-36</td><td>2-28</td><td>1-10</td><td>2-31</td><td>Zhongyimaleisuo</td></tr>
<tr><td>1-27</td><td>Zhongzhu 2</td><td>1-17</td><td>1-21</td><td>3-12</td><td>2-8</td></tr>
<tr><td>2-5</td><td>1-2</td><td>Zhuzong 1</td><td>1-6</td><td>1-39</td><td>4-1</td></tr>
</table>

Forest Chemicals Revew
www.forestchemicalsreview.com
ISSN: 1520-0191
July-August 2021 Page No. 1162-1176
Article History: Received: 12 May 2021 Revised: 25 June 2021 Accepted: 22 July 2021 Publication: 31 August 2021

	4-6	4-5	1-34	1-4	1-30	/	
	2-36	2-18	2-25	1-1	1-20	2-15	
	3-14	3-18	1-26	/	T-1	2-11	
	1-12	3-7	2-27	2-39	2-40	3-15	
	House 6	House 5	House 4	House 3	House 2	House 1	