Jurnal Agronomi Indonesia
(Indonesian Journal of Agronomy)

ISSN 2085-2916 | e-ISSN 2337-3652
August 2024, *52*(2), 217-225
DOI: https://dx.doi.org/10.24831/jai.v52i2.53915

Research Article

Leaf growth pattern and morphology of *Sauropus androgynus* (L.) Merr. in tropical lowland

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ABSTRACT

Chikurmanis or katuk (Sauropus androgynus (L.) Merr.) is a traditional leafy vegetable that is consumed widely in Indonesia. The leaf is rich in vitamins, minerals, nutrients, and dietary fiber. The study aimed to investigate the leaf growth pattern and morphological characteristics of the chikurmanis cultivated in the tropical lowland ecosystem. The research was conducted on local farmland in Marga Sakti Sebelat, Bengkulu, Indonesia on December 2023 by survey method. The results showed that the leaf of chikurmanis grew in the daytime and continued to grow at nighttime as indicated in midrib length, leaf width, and foliole number. It is likely that nighttime growth become predominant in chikurmanis. The plant was a type of shrub with complete organs of stem, branch, root, flower, and leaf. The leaf was arranged as a compound leaf with many folioles in opposite positions. Midrib length (M) x leaf width (W) with a zero intercept of linear regression was the most reliable predictor of leaf area with the formula Y = 0.4964MxW (R^2 = 0.9677).

Keywords: chikurmanis plant; *katuk*; leaf area estimation; morphological trait; traditional leafy vegetable

Edited by:
Andi Nadia Nurul Lathifa Hatta
BRIN

Received:
16 February 2024
Accepted:
27 August 2024
Published online:
18 September 2024

Citation:
Muda, S. A., Lakitan, B., Gustiar, F., Ramadhani [1], F., Rizar, F. F., Nurshanti, D. F., Ria, R. P., Ratmini, N. P. S., & Purwanto. (2024). Leaf growth pattern and morphology of Sauropus androgynus (L.) Merr. in tropical lowland. *Jurnal Agronomi Indonesia (Indonesian Journal of Agronomy)*, *52*(2), 217-225

INTRODUCTION

Chikurmanis (*Sauropus androgynus* (L). Merr.) or *katuk* in Indonesian is a perennial leafy vegetable in the tropics and is mostly consumed as a traditional vegetable (Platel & Srinivasan, 2017). Platel and Srinivasan (2017) described the leaf as rich in protein and micronutrients such as calcium, iron, zinc, β-carotene, vitamin E, and alkaloids. Bunawan (2015) stated that 100 g of fresh leaf contains 7.4 g of protein, 711 mg of calcium, 8.8 mg of iron, 15.9 mg of zinc, and 5600 μg β-carotene. Moreover, Zhang et al. (2020) stated that the chikurmanis plant has phytochemical, ethnopharmacological, and pharmacological activities. Khoo et al. (2015) previously stated that the chikurmanis plant has great potential as a medicinal plant. The chikurmanis plant is traditionally used as a medicinal plant in South Asia and Southeast Asia. Traditional herbs are used to relieve fever, treat ulcers and diabetes, improve eyesight, as well as reduce obesity and imperative herbs. This plant is also known to the public as vegetable and food coloring, which is believed to be a supplement to increase breast milk production (Zhang et al., 2020; Fikri & Purnama, 2020). The plant is also used as supplement feed for sheep and cows (Suprayogi et al., 2022; Tarigan et al., 2023).

Leaf has the most economic value in chikurmanis. On the other hand, leaf area is an important component as a general source for plant growth from photosynthesis. Weraduwage et al. (2015) stated that leaf area expresses plant capabilities on photosynthesis and transpiration rate. Thus, understanding the leaf growth pattern and plant morphology of chikurmanis as a traditional plant is important for future improvement as stated by Lakitan et al. (2021).

Wang et al. (2022) reported that plant morphology, especially leaf, can reflect plant adaptability to the environment, including climate. Leafy vegetable morphology is sensitive to environmental conditions (Giordano et al., 2021; Liu et al., 2020). Morphological alterations of leafy vegetables as a consequence of less favorable environments have been demonstrated (Adhikari et al., 2021; Ljubej et al., 2021; Hossain et al., 2022; Muda et al., 2023). Moreover, Ljubej et al. (2021) stated that kale (*Brassica oleracea* var. acephala) contains higher proline, total phenolic acid, and total flavonoids grown at 8 °C compared to 21 °C. Ostadi et al. (2022) reported that peppermint (*Mentha piperita* L.) under moderate and severe drought conditions have higher enzymatic activities, proline, total phenolics, and flavonoids than in a well-watered environment. The study aimed to investigate the leaf growth pattern and morphological characteristics of the chikurmanis cultivated in the tropical lowland ecosystem.

MATERIALS AND METHODS

Research site

The research was conducted on farmer land in Karya Pelita, Marga Sakti Sebelat (3°10'59.0" S, 101°42'59.0" E), North Bengkulu, Bengkulu, Indonesia in December 2023. The study adopted a survey method on selected samples. The research site was a lowland field surrounded by a swamp area that have been converted into a freshwater fish pond. The water table was 40 cm below ground level. Rainfall in the research site is shown in Figure 1.

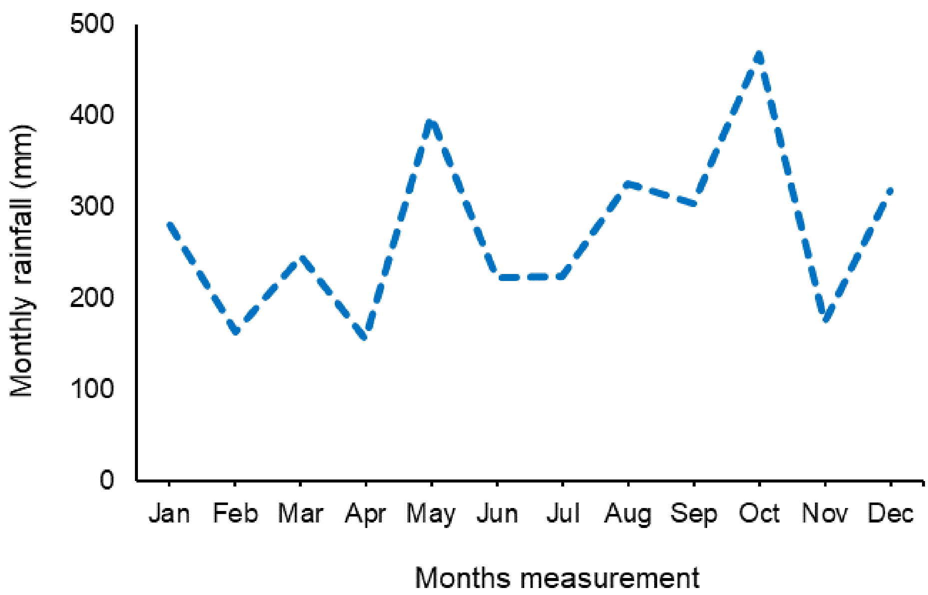

Figure 1. Monthly rainfall in research location in 2023 (Source: Central Agency of Statistics of Indonesia).

Plant materials

Chikurmanis field was a bund of freshwater fish pond sized 20 m (length) x 1 m (width) with a population of about 40 plants. The plant is aged 2 years and regularly harvested. The plant was cultivated through stem cuttings, and the planting material originated from normal and healthy mother plant. For observation, 10 plants were selected randomly. The irrigation used rainfall.

Observations

The selected chikurmanis plant was observed for its individual leaf growth. The observation of individual leaves started when it was fully unfolded. Observation was carried out in the morning at 06:00 and afternoon at 17:00 for three consecutive days on the same leaf. The leaf morphology included midrib length, leaf width, foliole number, and petiole length. Midrib length and leaf width were measured using a ruler.

Regarding the leaf area estimation, 50 normal leaves were randomly selected. The size of the compound leaf was chosen to be varied from small, medium, and large, randomly selected. The selected leaves were measured in areas using the Easy Leaf Area image scanner for Android device (Easlon & Bloom, 2014). To select the most reliable predictors, we examined the strength of the relationship between the leaf area with the selected predictors (Muda et al., 2023).

Midrib length was defined as the length of the middle leaf from the base to the tip of the leaf. Leaf width was measured horizontally at the widest side. Meanwhile, the foliole was small leaflets of the leaf (Figure 2).

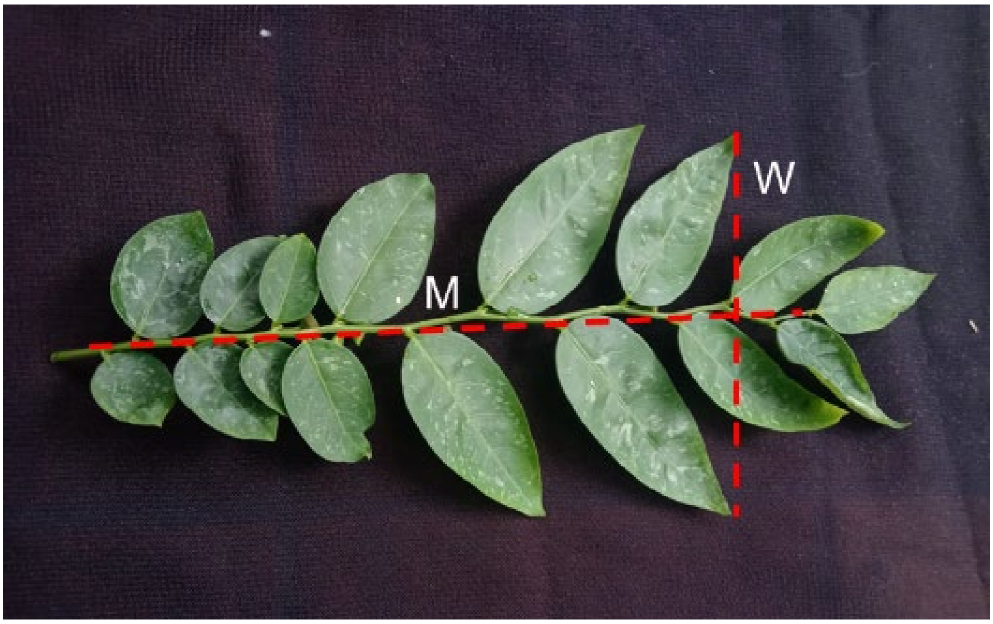

Figure 2. Leaf midrib (M) and leaf width (W) as predictors measured on leaf area estimation.

To observe the morphology of several organs of the chikurmanis plant, we conducted destructive observation. The observation used 10 plants. Furthermore, each plant organ was captured to get a morphological view of the chikurmanis plant.

Data analysis

The data collected were analyzed descriptively. Some selected parameters were tested for the strength of their relationship using simple regression, namely linear, exponential, polynomial, logarithmic, linear with zero regression, and exponential with zero regression. All data analysis was done using Microsoft Excel for Windows 10 (Microsoft Inc., Redmond, USA).

RESULTS AND DISCUSSION

Leaf growth pattern

Leaf growth of the chikurmanis plant generally continues to grow on a daily basis. The leaf continued to grow as indicated by the presence of growth meristem on the leaf tip. The increase in leaf growth of the chikurmanis plant was higher in the morning measurement than in the afternoon, indicating the high leaf growth at night. This phenomenon occurs in several leaf components measured such as midrib length, leaf width, petiole length, and foliole number. The condition was more pronounced at 2 days after leaf unfolding (DAU) (Figure 3).

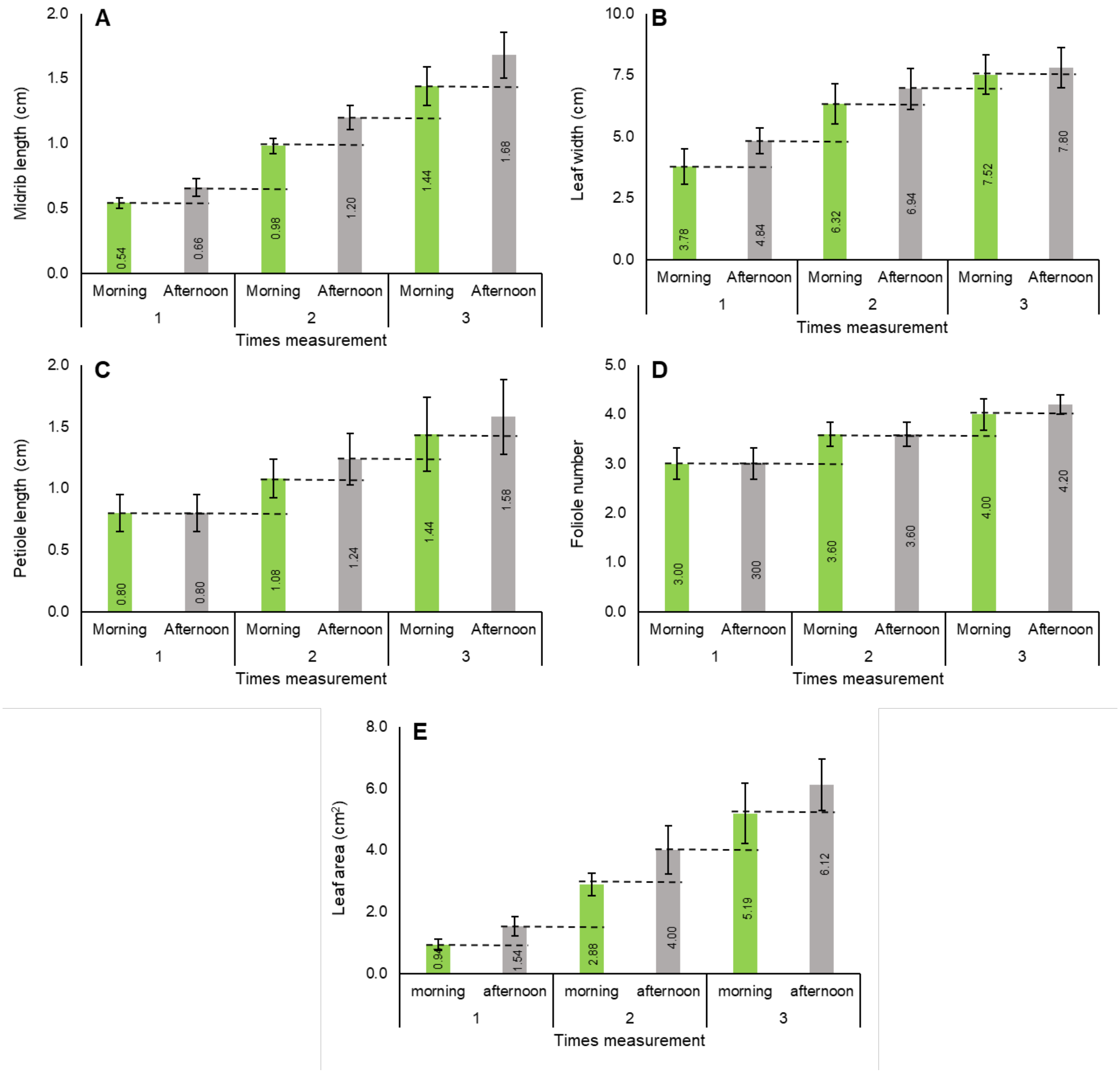

Figure 3. Daily leaf expansion of chikurmanis plant as indicated by midrib length (A), leaf width (B), petiole length (C), foliole number (D), and leaf area (E) in the morning and afternoon. The leaf area was estimated using Y= 0.4964 x midrib length (M) x leaf width (W).

In the daytime, the leaf growth acceleration was more dominant in the morning than afternoon. When the leaf size of the previous afternoon was compared to the following morning, it was evident the presence of marked nighttime growth. Such a growth pattern could be due to physiological processes in chikurmanis, but the process needs further observation. According to Smith and Zeeman (2020), starch degradation occurs at night so there is an allocation of carbon for plant organs. Moreover, Zweifel et al. (2021) stated that plant growth at night increases due to a decrease in vapor pressure deficit (VPD). The VPD is defined as the difference between saturated vapor pressure and actual vapor pressure at a given temperature and humidity. Vapor pressure conditions at night follow plant growth requirements. This condition caused the VPD to decrease (Lu et al., 2015). Song et al. (2021) confirmed that a decrease in VPD caused gas exchange in the stomata to occur more stably. It is probable that decreasing VPD reduces transpiration, increases cell water potential, and stimulates cell development and division, thereby increasing leaf growth in chikurmanis. Thus, to meet the physiological process and minimize the negative impact on plant growth, leaf harvesting in the chikurmanis plant is recommended in the morning.

Plant morphology

The chikurmanis plant formed a shrub. The chikurmanis plant shoot was dominated by branches with a short stem. The branch and stem are colored brownish at the lower position and green at the upper position (Figure 4A). A leaf is a compound with many folioles (leaflets) (Figure 4B). The foliole is a pinnate pattern and it was arranged on the midrib. Meanwhile, the foliole arrangement on the midrib is alternating between leaflets with an equal number in normal conditions. Compound leaf architecture like this is commonly referred to as paripinnate. The term paripinnate is used for compound leaf with pinnate foliole arranged in pairs along the leaf midrib. Another example of paripinnate leaf arrangement was seen in *Arapatiella psilophylla* (Rodrigues, et al., 2023) and *Vicia mingyueshanensis* (Xiao et al., 2021).

The flowers are located at abaxial, especially in the foliole axil (Figure 4C). Young flowers are green, then develop into brownish with purplish-red oval-shaped petals (Figure 4D). Tap roots were absent; it is probably due to the plant originating from cutting propagation. Fibrous roots dominated the rooting formation (Figure 4E). Primo-Millo and Agusti (2020) stated that plants cultivated by vegetative propagation are characterized by fibrous roots that develop more actively to absorb water and nutrients.

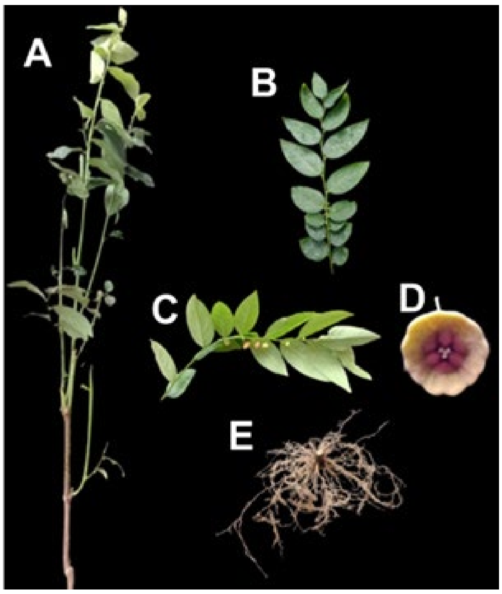

Figure 4. Morphological characteristic of chikurmanis plant’s organs. Shoot (A), leaf (B), flower position (C), flower (D), and roots (E).

Leaf area estimation

Based on the observation, the predictor midrib length (M) x leaf width (W) was concluded as the most reliable predictor for estimating leaf area. The best linear formula was set with zero intercept regression, i.e., Y= 0.4964MW (R^2=0.9677) (Table 1).

The natural distribution between data of each predictor and leaf area showed great variation. The midrib length (M) x leaf width (W) data had a more narrow data distribution as compared to the other predictors. In contrast, the foliole number showed a random and broad pattern of data distribution. This confirms the midrib length (M) x leaf width (W) as the most prospecting predictor to determine leaf area in the chikurmanis (Figure 5).

Leaf area can be estimated non-destructively through the regression method, and it is not exclusive to chikurmanis. Yu et al. (2020) stated that regression is a reliable estimate for leaf area in plants with several leaf shapes. In the present observation, the midrib length (M) x leaf width (W) predictor with linear with zero intercept regression was the most reliable than the others; this pattern is also applicable to habanero chili (Lakitan et al., 2022), celery (Lakitan et al., 2021) and citrus (Muda et al., 2023). Different plants could have different predictors since the leaf area is determined by leaf shapes and veins, such as in *Amorphophallus muelleri* (Nurshanti et al., 2022), chaya (Gustiar et al., 2023) and citrus (Budiarto et al., 2022).

Table 1. Relation between leaf area with midrib length, leaf width, and foliole number on chikurmanis plant.

Leaf component	Regression type	Equation	R^2
Midrib length (M)	Linear	Y= 9.3916M-29.595	0.8740
	Exponential	Y= $28.407e^{0.077M}$	0.7145
	Logarithmic	Y= 134.53ln(M)-233.69	0.7385
	Polynomial	Y= $0.0349M^2$+7.9612M-17.349	0.8757
	Power	Y= $3.2675M^{1.2788}$	0.8749
	Linear with zero-intercept	Y= 8.0296M	0.9637
	Polynomial with zero-intercept	Y= $0.0691M^2$+6.3115M	0.8739
Leaf width (W)	Linear	Y= 18.099W-102.09	0.7203
	Exponential	Y= $14.205e^{0.1558W}$	0.6760
	Logarithmic	Y= 221.91ln(W)-426.08	0.6692
	Polynomial	Y= $0.4201W^2$+6.3656W-26.25	0.7306
	Power	Y= $0.5669W^{2.0792}$	0.7264
	Linear with zero-intercept	Y= 11.063W	0.9026
	Polynomial with zero-intercept	Y= $0.5456W^2$+2.6127W	0.7276
MxW	Linear	Y= 0.4242MW+28.089	0.9065
	Exponential	Y= $49.007e^{0.0032MW}$	0.5985
	Logarithmic	Y= 94.566ln(MW)-364.08	0.8043
	Polynomial	Y= $-0.0003MW^2$+0.63MW-0.5684	0.9354
	Power	Y= $0.9694MW^{0.8944}$	0.9194
	Linear with zero-intercept	Y= 0.4964MW	0.9677
	Polynomial with zero-intercept	Y= $-0.0002MW^2$+0.627MW	0.9354
Foliole number (F)	Linear	Y= 12.767F-23.888	0.5544
	Exponential	Y= $27.582e^{0.1106F}$	0.5113
	Logarithmic	Y= 151.39ln(F)-235.66	0.5303
	Polynomial	Y= $0.0069F^2$+12.57F-22.658	0.5544
	Power	Y= $3.1577F^{1.4452}$	0.5472
	Linear with zero-intercept	Y= 11.136F	0.8883
	Polynomial with zero-intercept	Y= $0.1105F^2$+9.3408F	0.5530

Note: The R^2 indicates the strength level of regression.

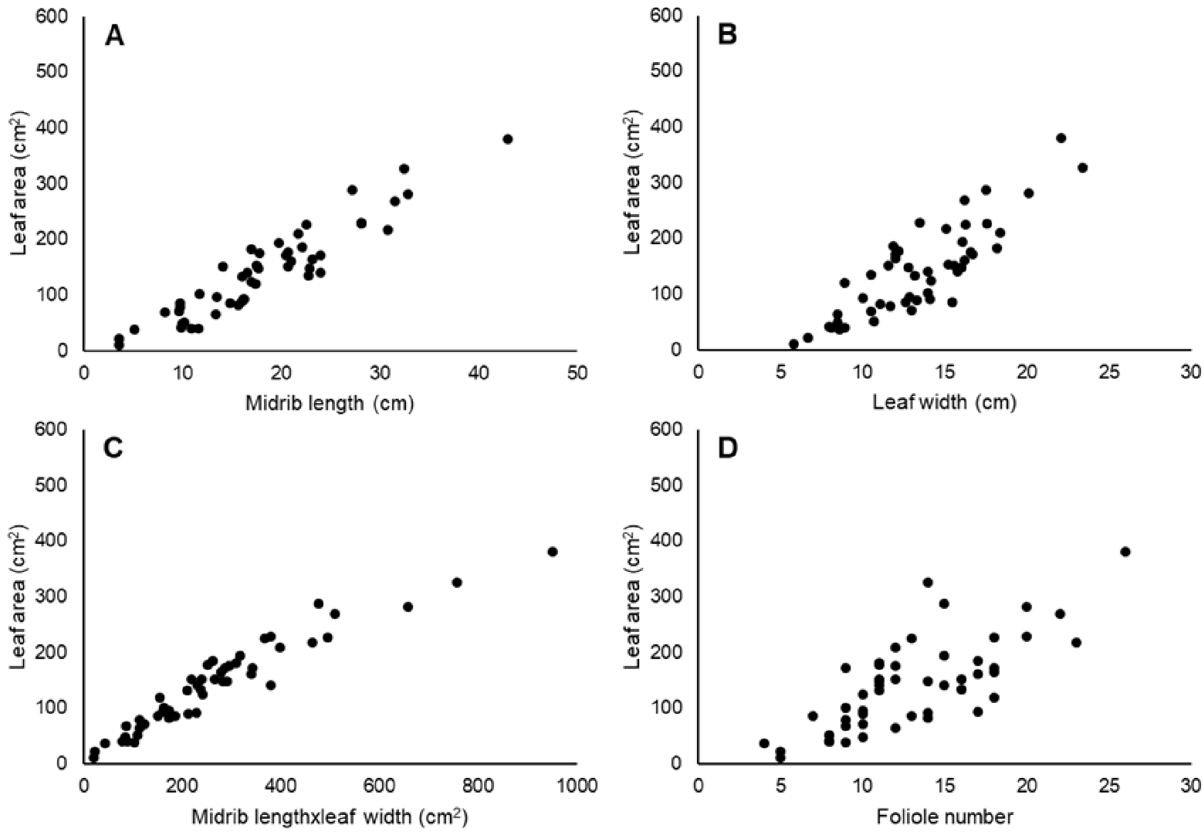

Figure 5. Distribution of data between midrib length (A), leaf width (B), midrib length x leaf width (C), and foliole number (D) with leaf area on chikurmanis plant.

CONCLUSIONS

Leaf size of chikurmanis increased more markedly at night time than in day time as seen in the following morning measurement than previous afternoon. Hence, harvesting is recommended in the morning after the plants have already experienced their metabolism at night. The leaf area of chikurmanis could be predicted using midrib length (M) and leaf width (W) using the formula of Y= 0.4964MW. It would be interesting in the future to study factors affecting nighttime growth in chikurmanis to increase plant production in the field.

ACKNOWLEDGEMENTS

We are very grateful to the local farmer who have helped and facilitated this research. We are also grateful to all colleagues who have supported this research.

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