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Performance of the petiole mobile application on the leaf area estimation as varied with calibration height

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Abstract
This study presents a new technique i.e., mobile application (Petiole), to estimate the leaf area, of two plant species (Neem & Rose), in the present study. It helps avoid the complex coding and algorithms required in the measurement of leaf area using the image processing techniques. The research's main objective was to evaluate the effect of the calibration height on the performance of the proposed new technique. The results exhibited that leaf area error was observed less than 1 cm^2, for both plant species. The study also showed a non-significant effect of calibration height on the performance of the mobile application. The maximum error (cm^2) was noticed with increasing calibration height from H_1 to H_3, but was less than 1 cm^2. This study also reported that results of leaf area estimated by the mobile application were agreed with that of the grid count method.

Keywords: Calibration height, calibration pad, leaf area estimation, mobile application, petiole

1. Introduction
The plant's morphological parameters are a medium through which, exchange of gases, energy and water takes place, especially through leaves and roots. Leaf area is a further prominent component of the plant leaf, used to predict the irrigation requirement based on evapotranspiration and the plant's productivity. It also influences the spraying system's performance on plant canopy in terms of spray uniform coverage, deposition and loss, as reported by (Warman *et al.*, 1981; Matthews, 1993; Ade, *et al.*, 2007) [1-3]. Hence, the speedy methodology is required for the measurement of the leaf area. Basically, the traditional methods are time-consuming, expensive, and laborious, such as graphical, gravimetric, and by using conventional planimeters.
On the other hand, some non-traditional methods are used for the leaf area estimation, like the Image processing methods, that are based on programming methods. Even though they provided good accuracy for the leaf area estimation for the different plant species as described by (Chaudhary *et al.*, 2012, Rico-García *et al.*, 2009) [4, 5], The problem of complex coding and algorithms made the image processing method uncommon for general researchers. Therefore, we presented a mobile application (Petiole) method to estimate the leaf area of the different plant species. Here, the prime goal of the study was to observe the effect of calibration height on the mobile application's performance, to verify the method's robustness and accuracy.

2. Materials and Methods
The experiments were performed on two plant species, at Central Institute of Agricultural Engineering, Bhopal, Madhya Pradesh. Ten leaves were taken from each plant species, such as Neem and Rose (Figure 1). Therefore, the total leaf sample size was 20, to be used for the estimation of the leaf area. In this research work, the grid count method was considered as a reference method for the leaf area estimation and compared with the mobile application (Petiole). The leaf area results estimated by the mobile application were verified with the grid count method.

Fig 1: (a) Rose leaf and (b) Neem plant leaf

2.1 Grid count method

The grid count method is treated as one of the most accurate methods for leaf area estimation. Therefore, many researchers used it as a reference method for comparison purposes (Shivling, *et al.*, 2011) [6]. Therefore, this study also scrutinizes it as a reference method.

2.2 Mobile application (Petiole) set up for the leaf area estimation at H_1: 8 cm

Petiole is a freely available mobile application, which was downloaded from the Google play store. After completing the petiole app's installation, it was opened by clicking the open option and allowed it to use the Google account for authentication of the user. It was followed by another click on the other option for measuring the leaf area. Consequently, two options emerged, such as 1st: set camera and 2nd: Get Petiole Pad option. The latter option was selected and automatically got the three types of calibration pad (small, medium and large size leaf) for calibration purposes on the initially registered Gmail account. In this study, the small calibration pad was used to estimate the leaf area of the two plant species as both plant species leaf selected for the experimen. comes under the small plant leaf category (Figure 2).

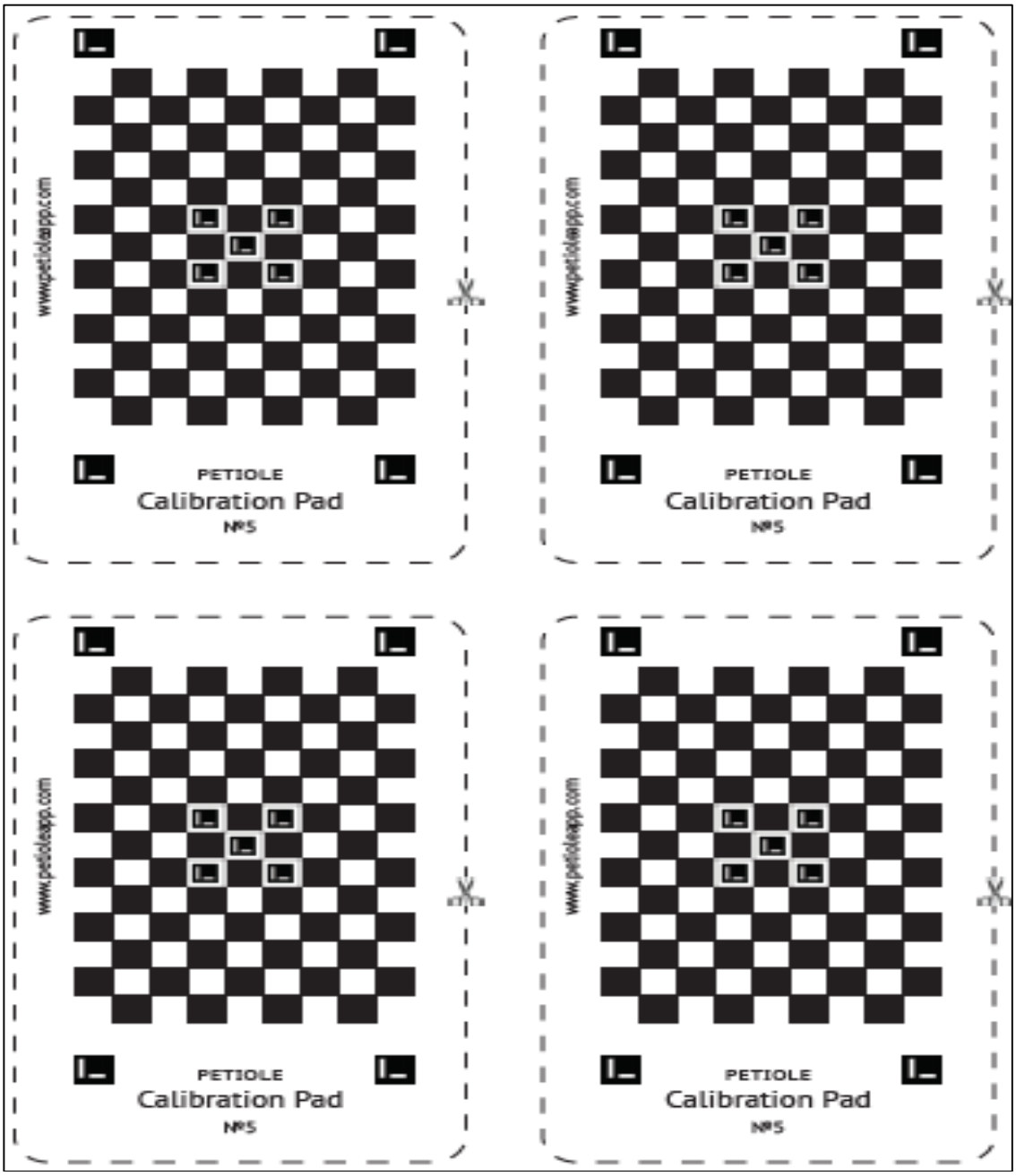

Fig 2: Calibration pad for small leaf (optimal height: 8 cm)

The small petiole calibration pad was placed under the mobile set up, at the desired height for the leaf area estimation (Figure 3).

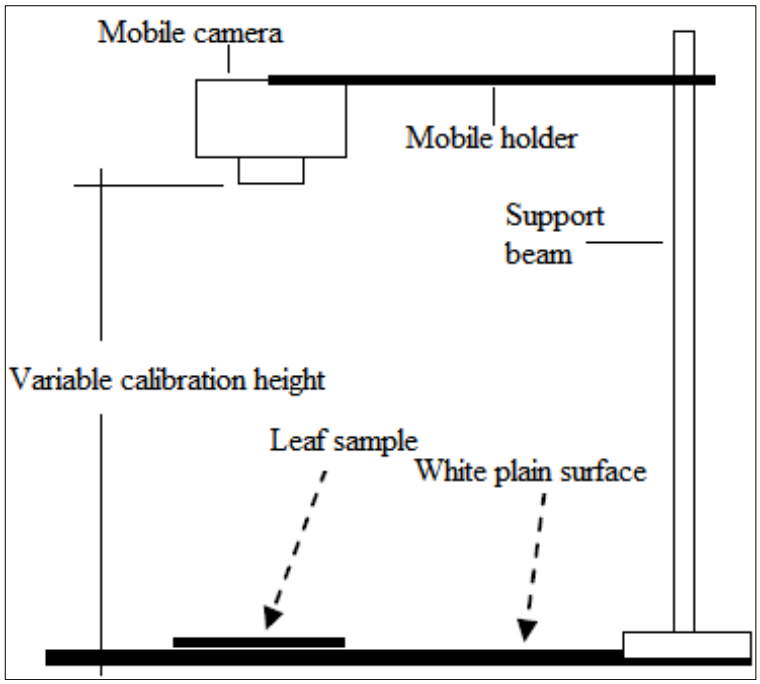

Fig 3: Mobile camera set up for the leaf area estimation

2.3 Effect of calibration height on the performance of the mobile application

It was calibrated separately at three heights (H1: 8 cm, H2: 12cm and H3: 16 cm) to determine the mobile application's accuracy. Ten leaves from each plant species were tested at these three heights using the same mobile application. The reading of all the leaf areas was recorded corresponding to the calibration heights. The effect of calibration height on the mobile application's accuracy for the same leaf of each plant species is shown (Figure 4).

Fig 4: Effect of calibration height on the accuracy of the mobile application for the same leaf of both Neem and Rose

3. Results & Discussion

3.1 Comparison between two methods for leaf area estimation

This study used two methods to estimate leaf area, such as grid count and mobile application method. Their results were compared to determine the accuracy and reliability of the mobile application (Table 1). The error (cm^2) was calculated for each of the plant species leaf using equation 1.

$$\text{Error} = (A_{gc} - A_p) \quad \ldots (1)$$

Where,

A*gc* is leaf area calculated by grid count,

A*p* is leaf area calculated by the Petiole mobile app.

The leaf area estimation for Rose and Neem plant species was evaluated by using the mobile application at the optimal height (H_1: 8 cm). The error in terms of centimeter square area was found less than 1 in all cases, for both plant species. In most cases, a negative error (cm^2) was observed because of the curvy shaped outer boundary of the leaf (Table1). However, in the grid count method, we can only draw the plain boundary of the leaf. Thus, the area for the same leaf was obtained higher in most cases while using the grid count method.

Table 1: Estimation of leaf area for Rose and Neem (at H_1: 8 cm)

Rose leaf area (cm^2)				Neem leaf area (cm^2)			
Sr. No.	**A*gc***	**A*p***	**Error**	**Sr. No.**	**A*gc***	**A*p***	**Error**
1	10.4	10.8	-0.4	1	9.7	10.0	-0.3
2	9.1	8.4	0.7	2	6.6	6.6	0.0
3	8.2	7.7	0.5	3	6.9	7.2	-0.3
4	8.6	8.3	0.3	4	6.1	5.6	0.5
5	10.2	9.8	0.4	5	6.5	6.4	0.1
6	7.7	7.6	0.1	6	7.8	7.6	0.2
7	8.9	9.2	-0.3	7	7.2	7.1	0.1
8	9.1	8.6	0.5	8	8.3	8.1	0.2
9	7.2	7.1	0.1	9	7.3	7.3	0.0
10	8.2	8.0	0.2	10	6.6	6.8	-0.2

3.2 Effect of the calibration height on the performance of the mobile application

The leaf area measurement for the same leaf was done using the mobile application at three different heights after the calibration. The same procedure was employed for the ten leaves of each of the plant species. The graph was plotted between error (cm^2) at three different heights as mentioned earlier, shown in (Figure 5 & 6). There was no significant effect of the calibration height on the accuracy of the mobile application for the leaf area estimation in both plant species.

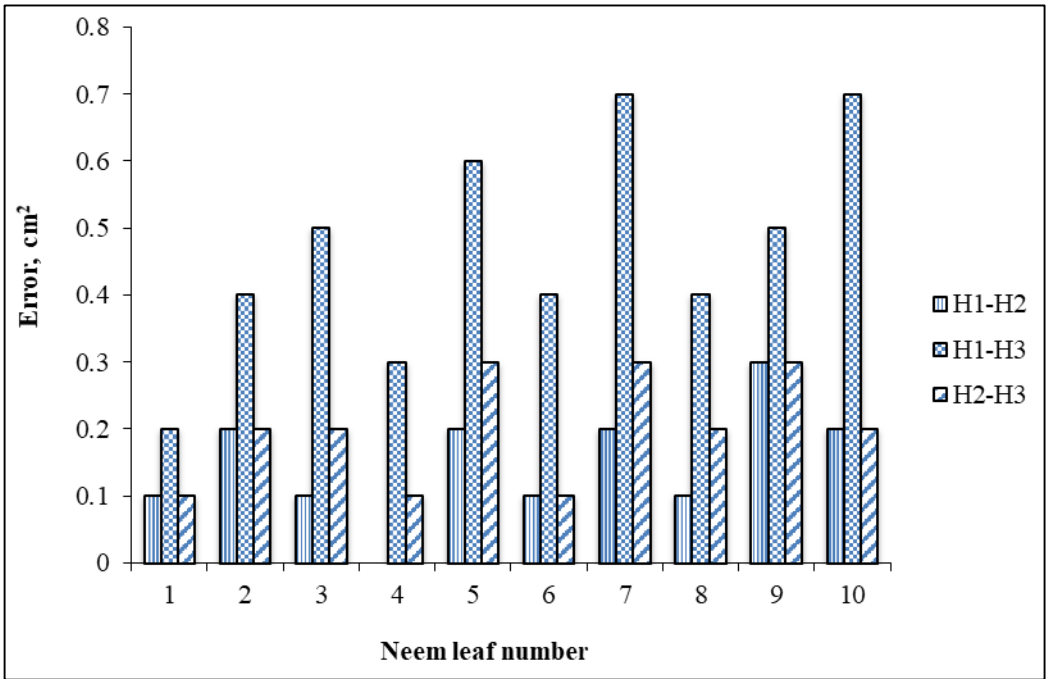

Fig 5: Estimation of error (cm^2) in Neem leaf at different calibration height (H_1: 8 cm, H_2: 12 cm and H_3: 16 cm)

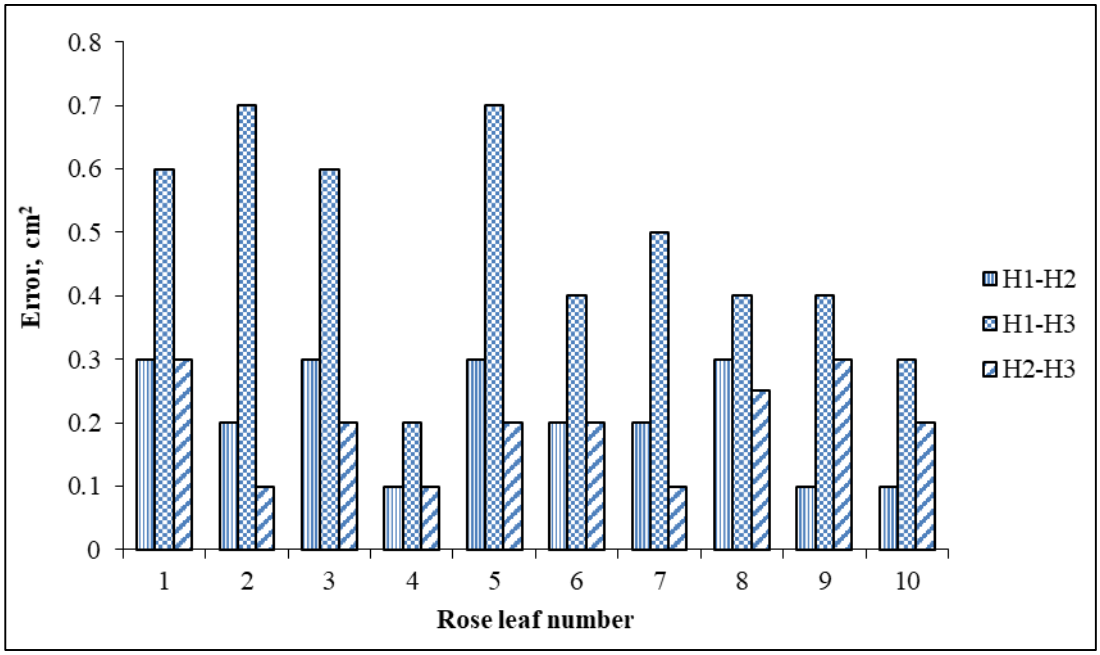

Fig 6: Estimation of error (cm^2) in Rose leaf at different calibration height (H_1: 8 cm, H_2: 12 cm and H_3: 16 cm)

4. Conclusions

The study confirmed the accuracy and robustness of the mobile application for measuring the leaf area of different plant species. The leaf area measurement results obtained by the mobile application method agreed with that of the grid count method. This study highlighted the mobile application's potential to minimize the problems associated with traditional methods like complex coding and algorithm, that is labor-intensive and is also expensive.

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