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Estimation of leaf area by mobile application: Fast and accurate method

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Abstract
There are numerous techniques for the estimation of leaf area. Every technique has some advantages and disadvantages over one another. This study proposed a new technique for the leaf area estimation i.e. mobile application (Petiole). It is a free of cost mobile application. The mobile application was used for the estimation of the leaf area of six different plant species. It was observed that error percentage for the leaf area estimation was recorded less than 4% in case of banyan, Jamun and lemon plant leaf. It was also concluded that less than 3 cm^2 area error was present for all the cases. This study confirmed the reliability, correctness and robustness of the mobile application for leaf area estimation. This study ensures the accuracy and capability of the petiole app to mitigate the problems of laborious, cumbersome and expensive experiments for the leaf area estimation and the method also saved a lot of time as compared to the other methods. It has the potential to avoid the complex coding algorithm for the program based techniques, usually adopted for the measurement of the leaf area.

Keywords: Calibration pad, grid count method, leaf area, petiole, plant species

1. Introduction
Leaf area is one of the principle elements of any tree or plant; which determines the radiation interception level, exchange of water and gases through the action of stomata known as the transpiration process. It helps the researchers to understand and establish the inter-relationship among the growth of plants, production, irrigation requirement and leaf area. Meanwhile, it also effects the pesticide application rate on the plant canopy in the form of spray deposition, ground loss, drift, penetration of spray droplet and uniformity of distribution (Warman *et al.*, 1981; Matthews, 1993; Ade, *et al.*, 2007) [1-3]. Therefore, a fast and accurate measurement of the leaf area (LA) is required. Basically, the methods of leaf area measurement can classified into two types of groups such as destructive or the non-destructive methods. The destructive methods are the traditional methods like graphical, gravimetric method, and by using a conventional planimeter. These methods are very laborious, expensive and time consuming and also degrades the canopy, when many number of leaves are plucked for the measurement of leaf area. On the other hand, a non-destructive method works on the basis of software application or algorithm, therefore, these are less expensive and user-friendly too. These methods revealed potential ability for the accurate measurement of the leaf area (Norman and Campbell, 1989) [4]. This study proposed a mobile application (Petiole) for the measurement of the leaf area. It will allow the researchers to avoid the complex coding and algorithm adopted for the program based leaf area measurement techniques.

2. Materials & methods
The study was conducted at Central Institute of Agricultural Engineering, Bhopal, Madhya Pradesh. The experiments were carried out on six different species of the plants such as banyan, Jamun, Peepal, guava, rose and lemon (Figure 1). Ten leaves were collected from each plant species in a randomized manner. Hence, total sample size was of 60 leaves, for the measurement of the leaf area. The study used mobile application (Petiole) and grid count method for the estimation of the leaf area for the collected leaf sample. The results of the mobile application were validated with the grid count method for the selected sample size.

Fig 1: Leaves of different plant species used in the study

2.1 Grid count method for measurement of leaf area

Various researchers have used the grid count method as a standard method for comparison of leaf area (Rico-Garcia, *et al.*, 2009; Shivling, *et al.*, 2011) [5-6]. Due the considerable accuracy of the grid count method, it was taken as reference in this study too. The desired sample size was taken from the six different plant species. The leaf area for the sample size was estimated by tracing the shape of every leaf on a graph paper.

2.2 Mobile application (Petiole) experimentation method for measurement of leaf area

Initially, mobile application (Petiole) was downloaded from the Google play store in an android operating system compatible mobile phone. After downloading the petiole app, the mobile app was opened by clicking the open option and then clicked on measure leaf area option. There were two options initially, first (set camera) and second (Get Petiole. Pad) option. Latter option was chosen out of these two options and received the calibration pad for mobile application on the registered Gmail account. There were three types of calibration pads available and were downloaded from the Gmail account for small, medium and large leaf size (Figure 2).

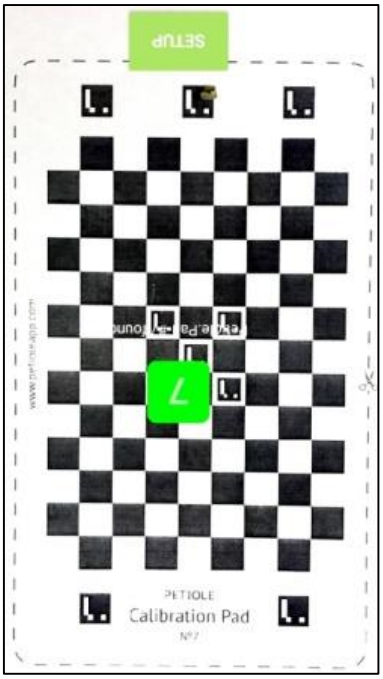
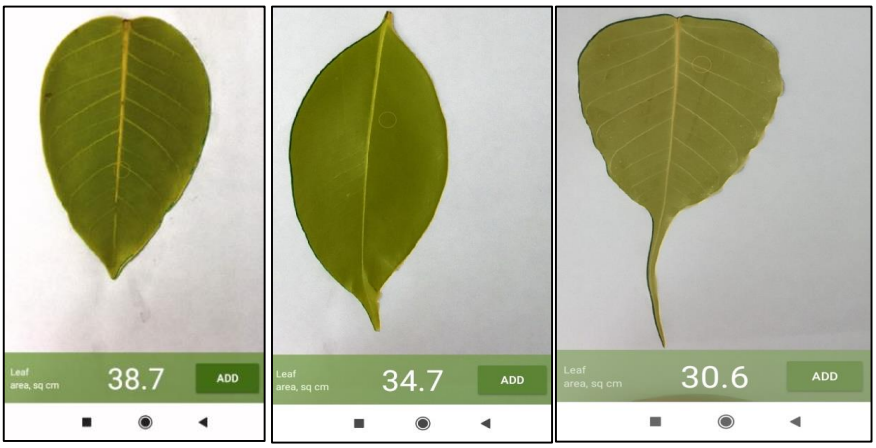
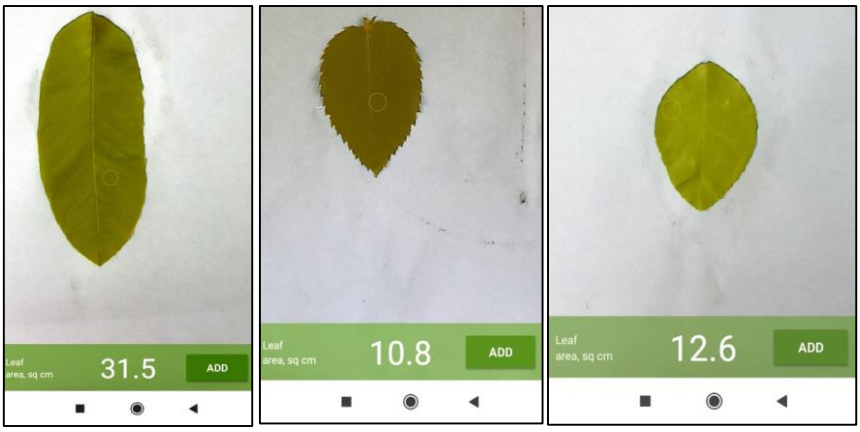


Fig 2: Calibration pad for medium leaf (optimal height: 11cm)

Again, the mobile application was reopened and followed the same procedure until two options appeared such as first (set camera) and second (Get Petiole). Now, this time, first option (set camera) was selected out of these two options, consequently, new window appeared and asked for the petiole pad calibration. The mobile was fixed at optimal height (11cm) as per given in the calibration pad and the placed the downloaded calibration pad under the mobile phone. It was calibrated using the calibration pad at the optimal height. Now, set up was ready for the leaf area estimation. The desired leaf samples were placed one by one and noted down the area corresponding to every leaf. However, only, single screenshot photo of estimated leaf area for each of the species were shown (Figure 3) on the account of limited paper space.



Banyan Jamun Peepal



Guava Rose Lemon

Fig 3: Estimation of leaf areas for the different plant species using the mobile application

3. Results & discussion

The estimation of desired leaf samples (60 leaves) was done by using two methods: grid count and mobile application method and then compared their results to determine the accuracy of the mobile application. The error percentage was calculated using equation 1.

$$\text{Error percentage} = \frac{(Agc - Ap) \times 100}{Agc} \quad \ldots (1)$$

Where, Agc = leaf area estimated by the grid count method
Ap = leaf area estimated by the mobile application

Here, leaf area of the five leafs from each plant species were only shown due to the account of paper space (Table 1).

Table 1: Results of leaf area obtained by mobile application and grid count method

Sr. No.	Leaf type	Leaf No.	*Agc* (cm^2)	*Ap* (cm^2)	Error (cm^2)	Error, %
1	Banyan	L_1	38.3	38.7	-0.4	-1.04
2		L_2	32.0	32.1	-0.1	-0.31
3		L_3	27.2	27.9	-0.7	-2.57
4		L_4	29.1	29.4	-0.3	-1.03
5		L_5	31.8	32.2	-0.4	-1.26
6	Jamun	L_1	34.2	34.7	-0.5	-1.46
7		L_2	28.3	28.2	0.1	0.35
8		L_3	26.2	26.9	-0.7	-2.67
9		L_4	26	26.3	-0.3	-1.15
10		L_5	30.3	30.5	-0.2	-0.66
11	Peepal	L_1	32.1	30.6	1.5	4.67
12		L_2	28.7	27.5	1.2	4.18
13		L_3	25	24.2	0.8	3.20
14		L_4	32.1	29.3	2.8	8.72
15		L_5	40.4	39.6	0.8	1.98
16	Guava	L_1	32.2	31.5	0.7	2.17
17		L_2	30.1	29.2	0.9	2.99
18		L_3	25.7	24.3	1.4	5.45
19		L_4	26.8	26.3	0.5	1.87
20		L_5	31.2	30.7	0.5	1.60
21	Rose	L_1	11.9	10.8	1.1	9.24

22		L_2	10	9.5	0.5	5.00
23		L_3	12.1	11.3	0.8	6.61
24		L_4	8.6	8.3	0.3	3.49
25		L_5	10.2	9.8	0.4	3.92
26	Lemon	L_1	12.4	12.6	-0.2	-1.61
27		L_2	12.9	12.9	0	0.00
28		L_3	10.1	10.4	-0.3	-2.97
29		L_4	14.3	14.4	-0.1	-0.70
30		L_5	13.8	14.3	-0.5	-3.62

Table 1 exhibits the potential ability of the mobile application for the leaf area estimation for different plant species. The mobile application provided minimum error for the leaf area, which highlights the accuracy of the method with reference to the standard grid count method. Whereas, the accuracy of the mobile application method was decreased in case of peepal, rose and guava plant species sample. The main reason for the declined accuracy of the mobile app in the peepal and rose plant could be the curvy outer periphery of their leaves. In grid count method, only smooth shapes of the leaves were traced using a pencil, hence positive error percentage was noticed in case of peepal and rose leaves. In addition, it was very difficult to trace curvy outer boundaries of the peepal and rose leaf by the pencil. In case of guava leaf sample, error percentage was also obtained positive, because of bending of the guava leaf during the fixing process of the leaf on the paper. Therefore, mobile application produced less leaf area with reference to grid count method, consequently positive error percentage was noticed.

4. Conclusions

The study described an insight, to estimate leaf area for the six different plant species. The Grid count and image processing was employed for the estimation of leaf area. The mobile application method is well known for its simplicity and induced accurate and fast results compared to the complex methods like grid count method, regression modeling and algorithm based image processing techniques. It also reduces the requirement of the expensive leaf area meter or planimeters. This study confirmed the reliability, correctness and robustness of the mobile application method for the leaf area estimation. It has capability to mitigate the problems of laborious work and time consumption associated with the traditional methods: i.e. Grid count method and gravimetric method.

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