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Simple models for non-destructive leaf area prediction in fig (*Ficus carica* L.) cv. Deanna and Poona

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Abstract

The edible fig (*Ficus carica* L.) has emerged as an important fruit in the world of commerce. Leaf area is an important parameter in fig research, especially for plant physiological studies. Most of the available methods for calculating plant leaf area are difficult to apply, expensive and destructive, which destroy the canopy, as a result of which it becomes difficult to perform further tests on the same plant. Therefore, an experiment was conducted to develop the statistical models for cv. Deanna and Poona of fig using regression analysis during 2010-11 for non-destructive estimation of leaf area. For this purpose the leaf area was recorded with the help of leaf area meter for 100 randomly selected leaves each for Deanna and Poona fig and leaf parameters were recorded for the same hundred leaves. Later, models for computing leaf area in non-destructive manner for cv. Deanna and Poona were developed separately by performing the regression analysis with regard to the relationship between leaf area and petiole length, left lobe (V2), middle lobe (V1) and right (V3) lobe. The statistical models for Deanna and Poona respectively were,

Y= -209.15+0.22*P+12.22*V1+6.42*V2+9.11*V3 (R^2 = 0.81) and
Y= -157.39+4.76*P+3.98*V1+6.57*V2+9.84*V3 (R^2 = 0.85).

The models developed by using the central lobe alone for Deanna and Poona fig respectively were Y=-200.91+24.51*V1 (R^2 = 0.77) and Y= -135.63+16.79*V1 (R^2 = 0.77). Further, the optimized models revealed that length of central lobe is sufficient to predict leaf area to an extent of 77% in Deanna and Poona.

Keywords: *Fig, leaf area, non-destructive, regression analysis, models*

Introduction

Leaf area is an important agronomical parameter as it is related to plant growth, photosynthetic activity and many times it is used to asses the effect of different plant treatments (Ali and Anjum, 2004). In fruit crops leaf area: fruit ratio determines the size and quality of fruits (Chacko, 1982). The optimum leaf number and area required for the development of individual fruit was worked out for mango (*Mangifera indica* L.) by Chacko (1982). The leaf area measurement is one of the most important parameter in agricultural research especially in plant physiology and nutrition. This parameter is a representative of plant growth and development. Its relationship with the absorption of light, respiration and photosynthesis is important. The leaf area index is a key structure for forest ecosystems properties and the reason is the roles that green leaves have on controlling physical and biological processes on vegetation cover. Therefore, accurate estimation of leaf area index is necessary for studying ecophysiology, interaction of the atmosphere and ecosystems and global climate change (Chen *et al*., 1997). Leaf area index is widely used to describe the vegetation photosynthesis and respiration levels. This index is also used extensively in ecophysiology, and water balance modeling and characterization of vegetation-atmosphere interactions (Rich *et al*., 1995). Determination of the leaf area is necessary for knowing how the energy transfers and dry matter accumulation processes in the vegetation. Leaf area is very important in the analysis of vegetation and also as a factor that makes possible to determinate the light interception, plant growth (Bhatt and Chanda, 2003). Many methods of measuring plants leaf area have been used but most of them are mix of several measurement models with complex and difficult mathematical equations. For example measuring leaf area by optical methods and image spectroscopy (Gosa *et al*., 2007) cannot be carried out everywhere. It is difficult even in methods such as using digital cameras and calculating the surface by computer programs; although taking photos is fast and very accurate analysis, but because of vast number

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of leaves this process takes a long time and often equipments are very expensive (Bignami and Rossini 1996; Lu *et al*. 2004). Other methods include, blue printing, photographic and planimeter. They all need to be separated leaves from the plants which cause the destruction of vegetation (Cristofori *et al*., 2007; Ugese *et al*., 2008).Portable scanning planimeters can quickly, accurately and non-destructively measure a leaf area (Daughtry, 1990), but it is suitable for small plants with few leaves (Nyakwende *et al*., 1997). Using a digital camera with image measurement and analysis software is also an alternative method of measuring leaf area. The capture of image by digital camera is rapid, but the processing procedure is time consuming and the facilities are generally expensive (Lu *et al*., 2004). Developing a rather inexpensive, rapid, reliable and non-destructive method for measuring leaf area becomes imperative for horticulturists and physiologists. By clarifying the mathematical relationship between leaf area and one or more dimensions of the leaf, a method using just linear measurements to estimate leaf area would be advantageous than many of the aforementioned methods (Villegas *et al*., 1981; Beerling and Fry, 1990). An equation was also developed for determination of leaf area in Thompson seedless grape using the recorded parameters of leaf like length of the main lobe (l_1), superior right lobe (l_2), superior left lobe (l_3) and breadth of the leaf (b) (Shikhamany *et al*., 1983).

The edible fig, *Ficus carica* L. cultivated since ancient times has emerged recently as an important fruit in world commerce. The highly nutritious fig fruits are habitually consumed dried or canned, but are also marketed fresh. Dried fig is high in calories, proteins, calcium and iron. Fresh fruits have a luscious taste and are wholesome, rich in carbohydrates and minerals, particularly iron. Figs are also prized for their mild, laxative action and are employed in the preparation of laxative confections and syrups (Chithiraichelvan *et al*., 2012). The Poona is a very popular Indian cultivar of fig. It gives small to medium size, purple colour fruits, suitable for table purpose, However, cv. Deanna introduced from U.S.A., is doing very well in India, particularly suitable as dried fig because of its yellowish green coloured fruits of medium to large size fruits. The objective of present study was to develop the statistical models for both the cultivars of fig for calculating the leaf area in non-destructive manner.

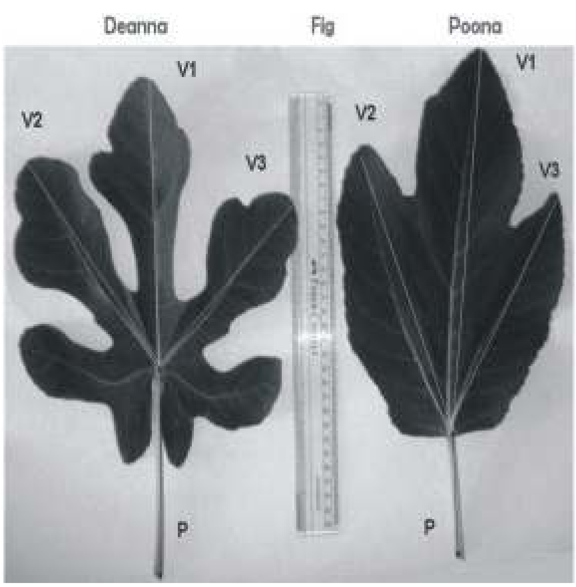

Figure 1. Leaf parameters for Cv. Deanna and Poona:

Materials and methods

The experiment was conducted at Indian Institute of Horticultural Research, Hessaraghatta Lake post, Bangalore-560089, Karnataka, India during 2010-11. The experiment was done on cv. Deanna and Poona. The leaf area was recorded with the help of leaf area meter for 100 randomly selected leaves for Deanna and Poona fig each as well as leaf parameters like petiole length and the lengths of vein (lobe) one, vein (lobe) two and vein (lobe) three were also recorded for same hundred leaves. Correlation analysis of leaf area and the independent variables P, V1, V2 and V3 were calculated (Figure 1). The data generated were fitted to linear regressions to establish the best fitted regression model using M S Excel (2010).

The scatter plots of various parameters for leaf area (P vs LA, V1 vs LA, V2 vs LA and V3 vs LA) in Deanna fig are presented in Figure 2 to 5; correlation matrix, fully

Table 1 : Regression models of leaf area estimation for Deanna fig in field conditions without destroying the plant, along with R^2 value

Parameters	Regression model	R^2
Petiole length (P)	Y= 17.072x + 63.989	0.27
Leaf lobe one (V1)	Y= 21.799x - 155.8	0.73
Leaf lobe two (V2)	Y= 23.358x - 114.76	0.63
Leaf lobe three (V3)	Y= 21.361x - 73.829	0.65
Taken together (P, V1, V2, V3)	Y= -209.15+0.22*P+12.22 *V1 +6.42*V2+9.11*V3	0.81
Taken central lobe (V1) only	y=-200.91+24.51*V1	0.77

Table 2 : Regression models of leaf area estimation for Poona fig in field conditions without destroying the plant, along with R^2 value

Parameters	Regression model	R^2
Petiole length (P)	Y= 22.693x + 54.69	0.48
Leaf lobe one (V1)	Y= 16.788x - 135.63	0.77
Leaf lobe two (V2)	Y= 21.397x - 104.81	0.70
Leaf lobe three (V3)	Y= 21.627x - 111.2	0.77
Taken together (P, V1, V2, V3)	Y= -157.39+4.76*P+3.98* V1+6.57*V2+9.84*V3	0.85
Taken central lobe (V1) only	Y= -135.63+16.79*V1	0.77

optimized model with statistics (Leaf Area Vs P+V1+V2+V3) for Deanna are presented in table 3; residual plots for Deanna parameters in Figure 6 to 9; correlation, fully optimized model with statistics and residual output for Deanna fig (V1 vs Leaf area) in table 4; scatter plots of various parameters for leaf area in Poona fig (P vs LA, V1 vs LA, V2 vs LA and V3 vs LA) in Figure 10 to 13; correlation matrix, fully optimized model with statistics for Poona fig (Leaf area Vs P+V1+V2+V3) in table 5; residual plots for Poona parameters in Figure14 to 17; correlation, fully optimized model with statistics and residual output for Poona fig (V1 vs Leaf area) in table 6.

The residuals are not either systematically high or low. They are centered on zero throughout the range of fitted values in all the models. In other words, the model is correct on average for all fitted values.

Under this study, the simple regression models were developed to estimate the leaf area of Deanna and Poona fig in non-destructive manner, which will be useful for physiological and nutritional studies. The results indicate that the leaf area of fig with high speed and accuracy can be obtained by measuring the petiole length and lengths of lobe one, two and three of the leaf without separating from the plant. Models were time saving and easily predictable. It makes possible to measure leaf area without destruction of plants, so, the sufficient vegetation will be available for conducting further tests. These models can be convenient and quick alternative, especially at places where there is no access to modern equipment or other devices for measuring the leaf area. This can be made further effective by using only the central lobe without much affecting the accuracy.

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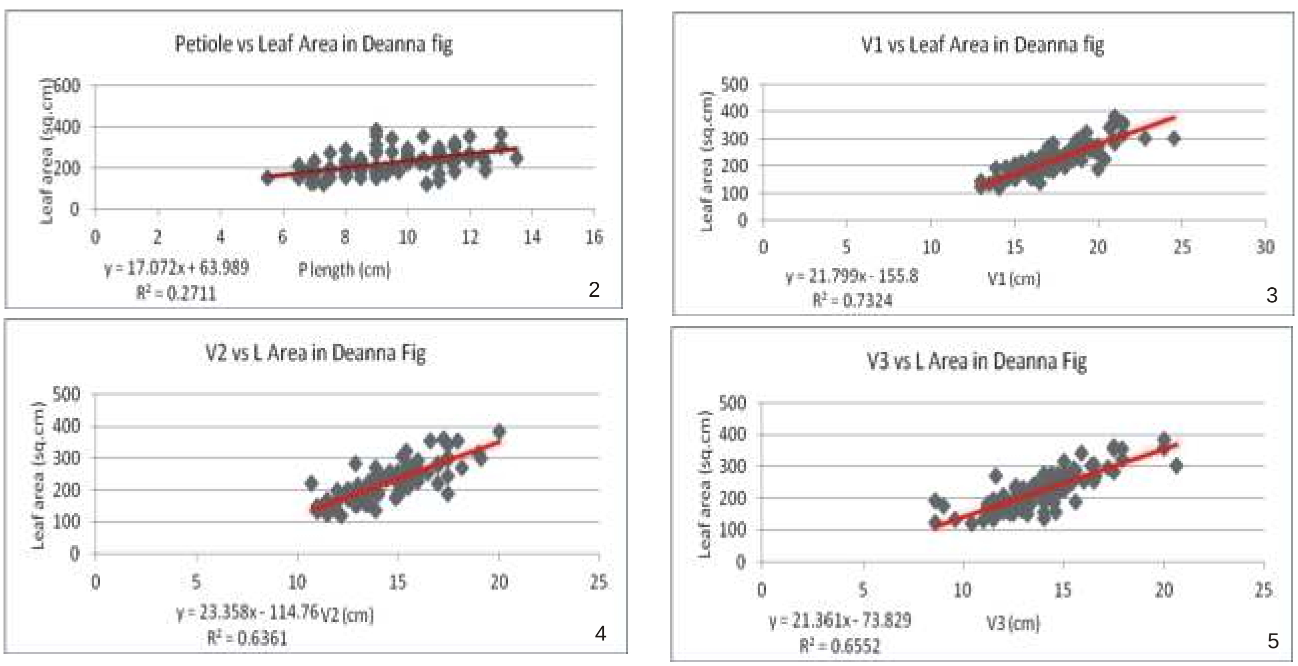


Figure 2 to 5: Scatter plots of various parameters for leaf area in Deanna fig

Table 3: Correlation matrix, fully optimized model with statistics (Leaf Area Vs P+V1+V2+V3) for Deanna fig

Correlation matrix

	Petiole	*V1*	*V2*	*V3*	*L Area*
Petiole	1				
V1	0.27838119	1			
V2	0.253681523	0.837132012	1		
V3	0.262215695	0.836754749	0.716021791	1	
L Area	0.287213435	0.875599586	0.798211824	0.83094418	1

Fully optimized modal	R2 (%)	SE
Y=-209.15+0.22*P+12.22*V1+6.42*V2+9.11*V3	81	28.51

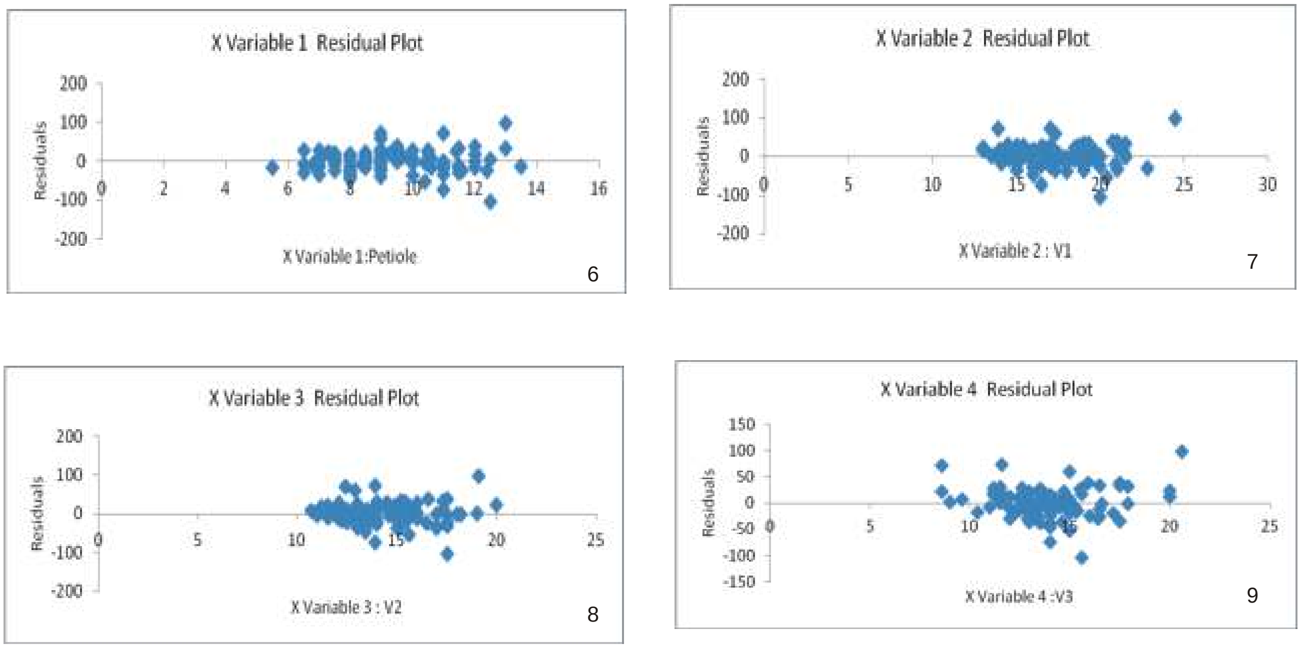


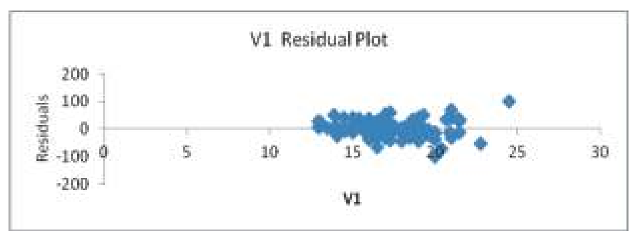
Figure 6 to 9 : Residual plots for Deanna parameters

Table 4. Correlation, fully optimized model with statistics and residual output for Deanna fig (V1 vs Leaf area) Correlation

	V1	*L Area*
V1	1	
L Area	0.875599586	1

Fully optimized modal	R2 (%)	SE
y=-200.91+24.51*V1	77	31.27

Residual output



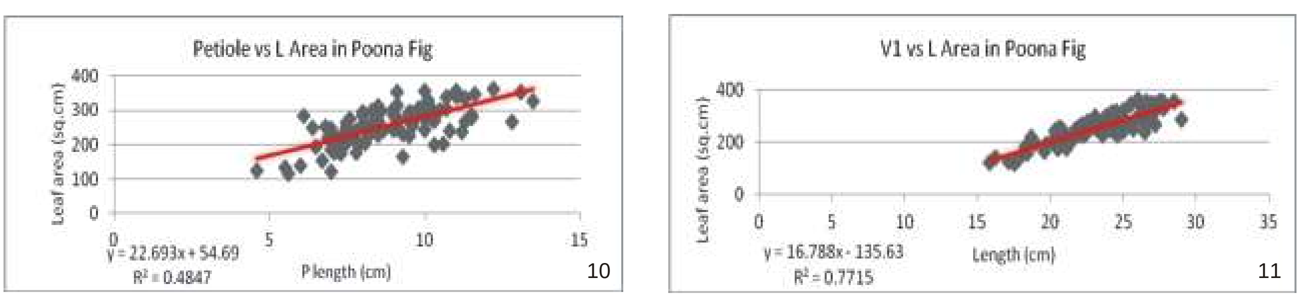
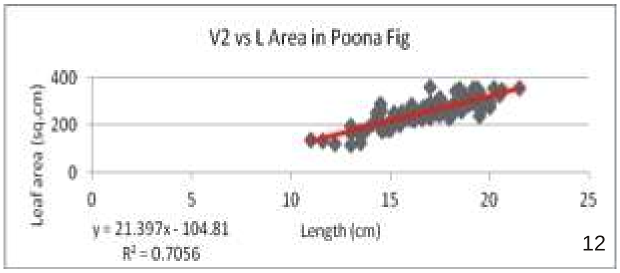


Figure 10 to 11 : Scatter plots of various parameters for leaf area in Poona fig



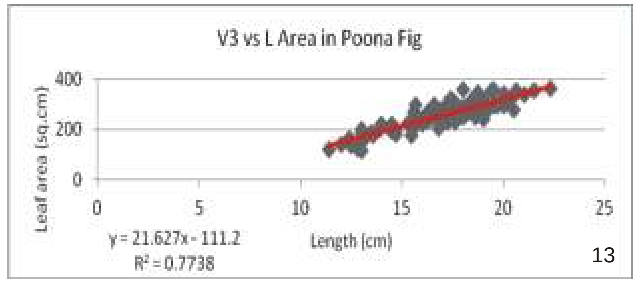
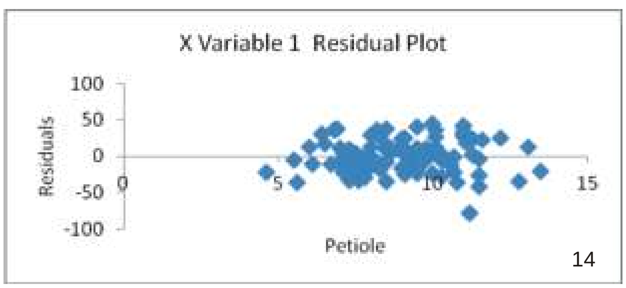


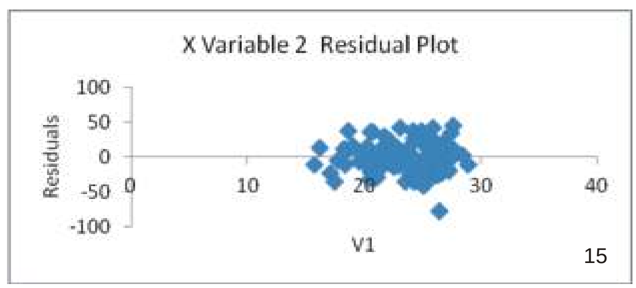
Figure 12 to 13 : Scatter plots of various parameters for leaf area in Poona fig

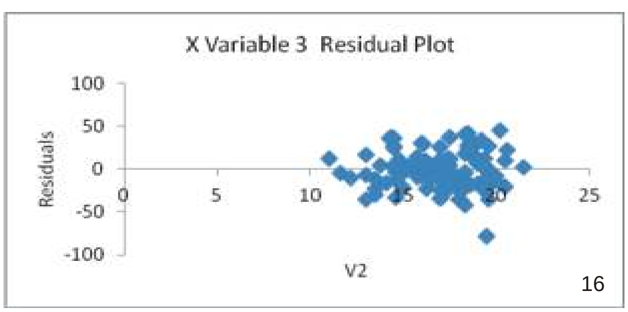
Table 5 : Correlation matrix, fully optimized model with statistics for Poon a fig
(Leaf area Vs P+V1+V2+V3)

Correla tion matrix

	Petiole	*V1*	*V2*	*V3*	*L Area*
Petiole	1				
V1	0.663223564	1			
V2	0.589940453	0.868979583	1		
V3	0.64910328	0.872100967	0.786806847	1	
L Area	0.696187394	0.878335581	0.840011919	0.879636746	1







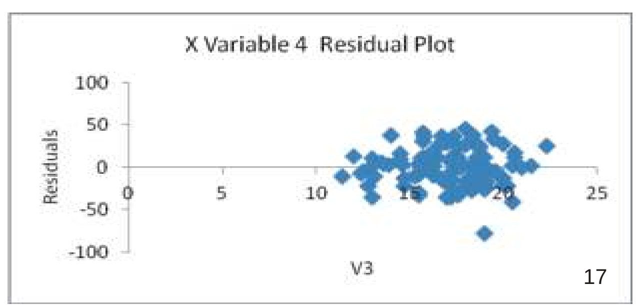


Figure 14 to 17 : Residual plots for Poona parameters

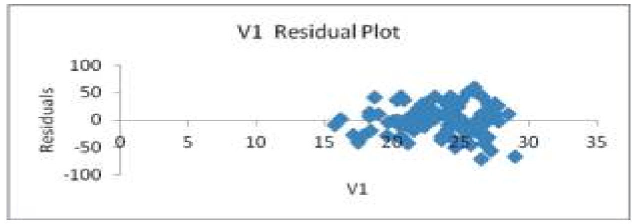
Table 6 : Correlation, fully optimized model with statistics and residual output for Poona fig (V1 vs Leaf area)

Correlation

	V1	L Area
V1	1	
L Area	0.878336	1

Fully optimized modal	R2 (%)	SE
Y= -135.63+16.79*V1	77	27.42

Residual output



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