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Leaf Area Estimation in Yam Bean (*Pachyrrhizus erosus* L.) using Linear Measurement of Leaf Parameters

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Abstract

Yam bean is a leguminous minor tuber crop grown in tropical regions for its turnip like edible tuberous roots for its delicacy. The seeds are protein rich and have insecticidal properties. So far, there is no information available in this crop for the estimation of leaf area; hence a simple method for leaf area estimation in yam bean (*Pachyrrhizus erosus* L.) was developed. In yam bean each leaf had three leaflets. Measurements on the length, breadth of leaflets of varying size were recorded. There was significant positive correlation between length (L) and area (A) (r = 0.889) and; breadth (B) and area (A) (r = 0.927) of leaflet. The factor (F) of relationship between L and A of leaf was 6.129 and that between B and A of leaflet was 5.569. The relation between product of length and breadth (P) and A of leaflet was also significant (r = 0.749) and the F between P and A was 0.643. The linear regression equation between L and A, B and A and between P and A were Y = 10.99x – 40.88, Y = 7.147x – 14.58 and Y = 0.571x + 5.702 respectively. The coefficient of determination (r^2) values between L and A, B and A; and P and A were 0.792, 0.860 and 0.933 respectively. The r^2 value observed between P and A near to 1 (0.933) suggested that the regression equation was good fit. Therefore, using the F value derived from P, the total leaf area of a plant can be calculated by the formula: Total leaf area = P of a single leaflet (average value of few observations) x 0.64 x 3 x total number of leaves per plant. The coefficient of determination between dry weight of leaflet to area was closer to 1 (r^2 = 0.903) and significant positive correlation coefficient value (r = 0.950) between weight of dry leaflet and area suggest that the dry leaf weight method can also be used for calculating leaf area of yam bean. The factor (F) derived between weight of dry leaflet and area of leaflet was 0.233. From the F value, the total area of yam bean can be calculated by the formula: Total leaf area = weight of a single dry leaflet (average of few leaflets) x 0.233 x 3 x total number of leaves per plant.

Key words: Yam bean, leaf area, dry leaf weight

Introduction

Tropical tuber crops are important sources of dietary energy and staple food for millions of people worldwide. They have the potential to substitute cereals owing to their high carbohydrate and calorie content. Among the tropical tuber crops, yam bean (*Pachyrrhizus erosus* L.) is a leguminous crop cultivated as a garden crop extensively for its edible tubers. It was introduced to different parts of tropical regions, with notable success in South-East Asia. Of the five species within the genus, three species, *P. ahipa, P. erosus* and *P. tuberosus* are cultivated. These species have a South American origin. Presently yam bean is cultivated widely in Mexico, China, Singapore, Philippines, Hawaii, Indonesia and India (Vimla and Nambisan, 2011). In India, *P. erosus* is cultivated and consumed as a salad crop in West Bengal, Odisha, Bihar and Jarkhand. On the other hand, it is grown by small communities located in the subtropical east Anden valleys of Bolivia and northern Argentina (Sorensen, 1996). Its flavour resembles that of water chestnut but is sweeter and can be added to salads. It is also used as a fodder and

green manure crop (Sen, 1999). The combination of multiple uses, high tuber yield, biomass production, nutritional value, low fertilizer and pesticide requirements and its good climatic and edaphic adaptability appear to be unique for this crop (Umamadhavan and Potty, 2010).

Leaf area is an important factor which intercepts solar radiation and determines crop productivity. There are different methods by which leaf area of crops can be calculated. The methods includes linear measurement, dry leaf weight, leaf area meter and imaging method. Non-destructive linear measurement for leaf area estimation have been reported for cassava, sweet potato, arrow root, elephant foot yam, taro and Chinese potato. The present paper reports the linear measurement method and dry leaf weight method for estimation of leaf area in yam bean.

Materials and Methods

Healthy seeds of yam bean (*P. erosus*) was planted in the farm of ICAR-Central Tuber Crops Research Institute (ICAR-CTCRI), Thiruvananthapuram, Kerala, India, during the month of June 2016. The crop was grown with drip irrigation system. Seeds were sown at 60 cm x 30 cm spacing. Farmyard manure (FYM) @ 10 t ha^{-1} and fertilizers to supply NPK @ 80:60:80 kg ha^{-1} was applied. Nitrogen 50% , full dose of Phosphorus and 50% Potassium was applied as basal dose and remaining N and K applied one month after sowing. At the age of three months, the length of individual leaflet (L) was measured from the leaf apex to the point of attachment to the petiole whereas maximum breadth (B) of leaflet was measured across the margins. The actual area (A) of individual leaflet was recorded in a leaf area meter, LICOR, USA (Model. No. LI - 3000C). The correlation coefficients (r) and the regression coefficient (r^2) and the regression equation $Y = a + bx$ between leaflet length (L) and area (A), breadth (B) and area (A) and product of length and breadth (P) and area (A) and between weight of dry leaflet and area (A) were calculated. The leaflets were also oven dried at 70° C to constant weight and the dry weights were recorded. the leaf factor was derived from the formula: Factor (F) = Area of leaflet (A) / leaflet length (L) or leaflet breadth (B) or product of leaflet length and breadth (P) or weight of dry leaflet as described by Ramanujam and Indira (1978).

Results and Discussion

Linear measurement method

The yam bean has compound leaves (trifoliate). Individual leaf is divided into three leaflets (Fig. 1). The length of each leaflet varied between 4.9 and 11.5 cm, breadth between 4.6 and 14.9 cm and the area between 14.32 and 88.91 cm^2. In the present study, the total number of compound leaves per plant at 3 months after planting varied between 20 and 36, while the average number of leaves per plant was 28.89. The regression equation between length (L) and area (A) of leaflet ($y = 10.99x - 40.88$) and the regression coefficient value ($r^2 = 0.792$) and the correlation coefficient value ($r = 0.889$) ($p = < 0.01$) showed that there was a highly significant positive correlation between L and A of a leaflet. The factor (F) derived between length and area of leaflet was 6.129 (Table 1). The regression equation between breadth (B) and area (A) of leaflet ($y = 7.147x - 14.58$) and the regression coefficient value ($r^2 = 0.860$) and the correlation coefficient value ($r = 0.927$) ($p = < 0.01$) showed that there was a highly significant positive correlation between B and A of a leaflet. The factor (F) derived between breadth and area of leaflet was 5.569 (Table 1). The regression coefficient equation for the relation between product of length and breadth (P) and area (A) of leaflet was calculated and the leaf factor (F) was derived by the linear measurement method. The regression equation between P and A ($y = 0.571x + 5.702$), the regression coefficient value ($r^2 = 0.933$) and the correlation coefficient value ($r = 0.749$) ($p = < 0.01$) clearly showed that there was a significant positive correlation between P and A of a leaflet (Fig. 2, Table 1). This suggested the suitability of linear measurement method for determining area of leaflet of yam bean. High positive correlation between P and A has been reported elsewhere in tannia (Chapman, 1964; Venkateswaralu and Birader, 1980; Agueguia, 1993), taro (Birader et al., 1978; Lu et al., 2004), cassava and sweet potato (Ramanujam and Indira, 1978; Lockard et al., 1985), white yam, greater yam and lesser yam (Ravi and Roy Chowdhury, 1989), dwarf white yam (James George, 1992), elephant foot yam (Ravi et al., 2010), Chinese potato (Ravi et al., 2011) and arrow root (Ravi and Suja, 2012). The factor (F) derived between product of length and breadth (P) and area of leaf (A) by linear measurement method was 0.643. The regression coefficient (r^2) value observed between P

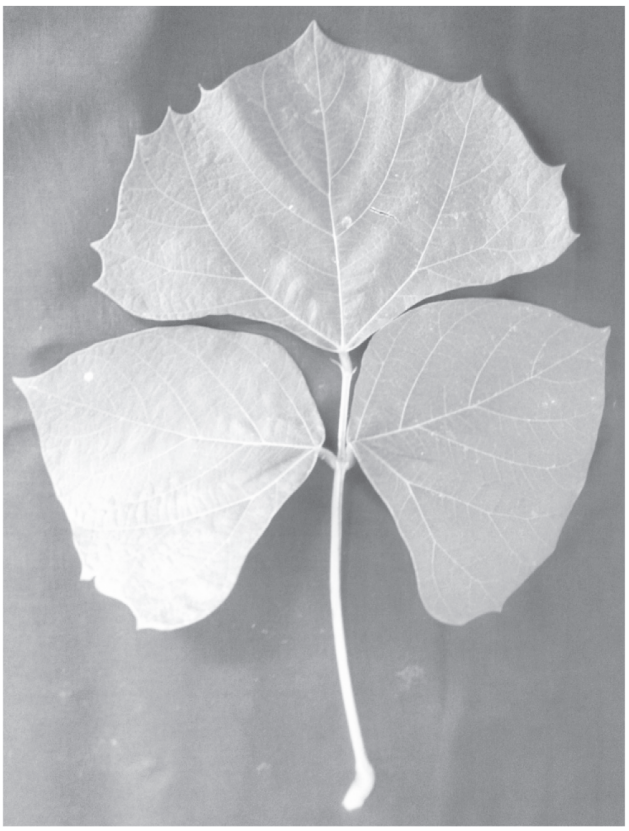

Fig.1. Leaf of yam bean.

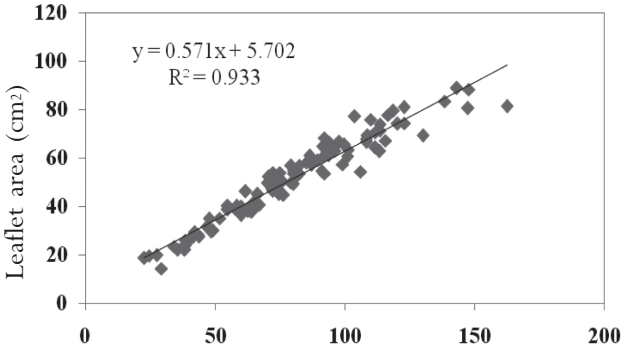

Fig. 2. Linear relationship between product of leaflet length and breadth (P) to its area (A) in yam bean.

and A was near to 1(0.933) indicating that the regression equation was good fit. When the values of leaflet area (A) based on leaf factor (F) derived from L, B and P were calculated and matched with actual value of leaflet area recorded in the leaf area meter, the difference was not significant and was the minimum in the case of product of length and breadth (P) of leaflet. Therefore, from the F derived for P, total leaf area of yam bean (A) per plant can be calculated by using the following formula: Total leaf area = P of single leaflet (average value of few observations) x 0.643 x 3 x total number of leaves per plant.

Dry leaf weight method

The weight of single dry leaflet varied between 61 mg and 530 mg and the average weight of dry leaflet was 220.63 mg. The leaflet area and weight of dry leaflet showed a significant positive correlation coefficient value ($r = 0.950$ significant at $p = < 0.01$), linear association ($y = 0.182x + 11.17$) and coefficient of determination value closer to 1 ($r^2 = 0.903$) (Table 1). This suggested that the dry leaflet weight method can also be used for calculating leaflet area of yam bean. The factor (F) derived between dry leaflet weight and area was 0.233 (Fig. 3, Table 1). From the F value the total leaf area of yam bean plant can be calculated by the formula: Total leaf area = Weight of single dry leaflet (average of few observations) x 0.233 x 3 x total number of leaves per plant. A positive correlation between weight of dry leaf and area has been reported in other crops like cotton (Ashley et al., 1963), cassava and sweet potato (Ramanujam and Indira, 1978), taro (Biradar et al., 1978), elephant foot yam (Ravi et al., 2010), Chinese potato (Ravi et al., 2011) and arrow root (Ravi and Suja., 2012).

Comparing the above two methods, the linear measurement method based on P seems to be more suitable for the calculation of leaf area in yam bean due to

Table1. Statistical relationship between leaf parameters with area in yam bean.

Leaf parameter	Regression equation (y= a + bx)	Regression coefficient (r^2)	Correlation coefficient (r)	Factor (F)
Length versus area (L)	10.99x - 40.88	0.792	0.889	6.129
Breadth versus area (B)	7.147x – 14.58	0.860	0.927	5.569
Product of length and breadth versus area (P)	0.571x + 5.702	0.933	0.749	0.643
Weight of dry leaflet versus area	0.182x + 11.17	0.903	0.950	0.233

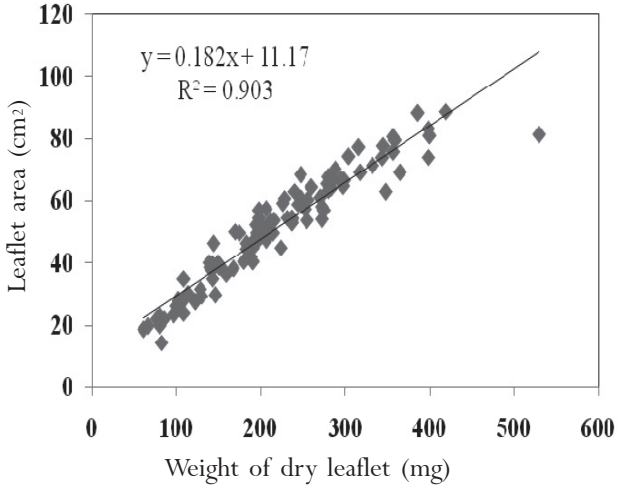

Fig. 3. Linear relationship between weight of dry leaflet and its area (A) in yam bean.

positive association between the P and A of leaf. The factor (F) derived by this method can be directly used for leaf area calculation in non-destructive growth analysis studies. Furthermore, the F derived by linear measurement method for leaf area measurement remains constant with age of the plant under wide environmental conditions (Ramanujam and Indira, 1978). Although the dry leaf weight method as per the present study can be used for determining the leaf area it cannot be used for non-destructive growth analysis studies.

Conclusion

Comparing the above two methods, the linear measurement method based on P and dry leaf weight methods seems to be more suitable for the calculation of leaf area in yam bean. The factor (F) derived by this method can be directly used for leaf area calculation in non-destructive growth analysis studies.

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