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Leaf Area Estimation in Arrowroot (*Maranta arundinacea* L.)

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Abstract

A method for leaf area determination in arrowroot (*Maranta arundinacea* L.) was developed at Central Tuber Crops Research Institute, Thiruvananthapuram, India. There was significant positive correlation between length (L) and area (A) ($r = 0.922$) and breadth (B) and area (A) ($r = 0.955$) of leaf. The factor (F) of relationship between L and A of leaf was 5.733 and that between B and A of leaf was 17.769. The relation between product of length and breadth (P) and A of leaf was also significant ($r = 0.994$) and the F between P and A was 0.761. The linear regression equation between L and A, B and A and between P and A were $Y = 11.98x - 141.1$, $Y = 29.14x - 81.22$ and $Y = 0.743x + 2.861$ respectively. The coefficient of determination (r^2) values between L and A, B and A and between P and A were 0.850, 0.911 and 0.987 respectively. The r^2 value observed between P and A near to 1 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 leaf (average value of few observations) x 0.761 x total number of leaves per plant. The coefficient of determination closer to 1 ($r^2 = 0.900$) and significant positive correlation coefficient value ($r = 0.949$) between area and weight of dry leaf suggest that the dry leaf weight method can also be used for calculating leaf area of arrowroot plant. The factor (F) derived between weight of dry leaf and area of leaf was 0.268. From the F value, the total area of arrowroot can be calculated by the formula: Total leaf area = weight of a single dry leaf (average of few leaves) x 0.268 x total number of leaves per plant.

Key words: Arrowroot, leaf area, dry leaf weight

Introduction

Arrowroot commonly known as West Indian arrowroot (*Maranta arundinacea* L.) is an unexploited crop with edible rhizomes containing 16-20% starch, valued as food particularly for infants and invalids. A comprehensive analysis of the basic pattern of growth and development of a crop is useful to elucidate the response of the crop to various inputs and helps in deciding the agronomic practices to exploit its yield potential. The total leaf area of a plant or the size of a canopy is a determinant factor in radiation interception, growth, water use efficiency and gas exchange ability related to photosynthesis of the plant, which ultimately decides the yield. The total dry matter produced by a plant per unit time is more dependent on the size of its total assimilatory system (Watson, 1952). The determination of total leaf area per plant and the leaf area index (LAI) i.e. leaf area per unit area of land is essential for growth analysis studies. Therefore, accurate measurements of LAI are essential to understand the interaction between crop growth and environment and thereby optimize crop management.

Among the various methods available, use of leaf area meter to measure leaf area is the best due to rapidity, accuracy and convenience. However, this instrument is expensive and cannot be used for non-destructive growth analysis studies. Therefore, alternative methods have been developed by many researchers to determine the leaf area of plants. Although digital camera with image measurement and analysis software is accurate, it is time consuming and expensive. The portable scanning planimeter is suitable only for small plants with few leaves but requires the excision of leaves from the plant (Nyakwende et al., 1997). An inexpensive, reliable, rapid and non-destructive linear measurement method based on the linear regression relationship between leaf length (L), leaf breadth (B) and product of leaf length and breadth (P) with leaf area (A) has been reported in several tropical tuber crops *viz.*, cassava and sweet potato (Ramanujam and Indira, 1978; Villegas et al., 1981), taro (Birader et al., 1978; Goenaga and Singh, 1996), tannia (Venkateswaralu and Birader, 1980), 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) and Chinese potato (Ravi et al., 2011). The advantage of this method is that it can be used effectively to estimate the area of intact leaves, which is vital in non-destructive growth analysis studies. The dry leaf weight method of determining area per unit weight of dry leaves and multiplied by total weight of dry leaves has been reported in wheat (Watson, 1937; Aase, 1978). The method is more suitable for plants with smaller leaves and more number of leaves (Palit and Bhattacharyya, 1984). Hence this paper reports the linear measurement method for determination of leaf area in arrowroot (*Maranta arundinacea* L.) which can be used for non-destructive growth analysis of this crop.

Materials and Methods

A promising selection of arrowroot (Ac.no.1) from the germplasm collection of Central Tuber Crops Research Institute (CTCRI), Thiruvananthapuram, Kerala, India, was planted under partial shade (40-45% shade) in May during 2005-2006 and 2006-2007. The crop was grown rainfed taking advantage of the bimodal rainfall received at the location and harvested after nine months in January. Rhizome pieces of size 20-25 g were planted at 30 x 15 cm spacing. Farmyard manure (FYM) @ 10 t ha^{-1} and fertilizers to supply NPK @ 50:25:75 kg ha^{-1} was applied. One hundred fully expanded leaves representing different sizes were taken randomly at 3, 5 and 7 months after planting. The leaf length (L) was measured from the leaf apex to the point of attachment to the petiole whereas maximum breadth (B) of leaf was measured across the margins. The leaves were also oven dried at 70°C to constant weight and the dry weights were recorded. The actual area (A) of individual leaf 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 leaf length (L) and area (A), breadth (B) and leaf area (A) and product of length and breadth (P) and leaf area (A) and between weight of dry leaf and leaf area (A) were calculated and the leaf factor was derived from the formula:

Factor (F) = Area of leaf (A) / leaf length (L) or leaf breadth (B) or product of leaf length and breadth (P) or weight of dry leaf as described by Ramanujam and Indira (1978).

Results and Discussion

Linear measurement method

The arrowroot plant has on an average 15-30 solitary leaves attached to the pseudostem. The area of individual leaves varied between 54.64 and 302.84 cm^2 with the average area of 139.29 cm^2. The length of leaves varied between 14.8 and 33.8 cm and the average length was 23.37 cm. The breadth of leaves varied between 4.1 and 12.4 cm with the average of 7.56 cm. In the present study, the total number of leaves per plant at 3, 5 and 7 months after planting varied between 11-18, 14-34, 19-39 respectively, while the average number of total leaves per plant was 14, 25 and 30 respectively.

The regression equation between length (L) and area (A) of leaves ($y = 11.98x – 141.1$) and the regression coefficient value ($r^2 = 0.850$) and the correlation coefficient value ($r = 0.922$) ($p = < 0.01$) showed that there was a highly significant positive correlation between L and A of a leaf. The factor (F) derived between length and area of leaf was 5.733 (Table 1). The regression equation between breadth (B) and area (A) of leaf ($y = 29.14 x – 81.22$) and the regression coefficient value ($r^2 = 0.911$) and the correlation coefficient value ($r = 0.955$) ($p = < 0.01$) showed that there was a highly significant positive correlation between B and A of a leaf. The factor (F) derived between breadth and area of leaf was 17.769 (Table 1). The regression coefficient equation for the relation between product of length and breadth (P) and area (A) of leaf was calculated and the leaf factor (F) was derived by the linear measurement method. The regression equation between P and A ($y = 0.743 x + 2.861$), the regression

Table 1. The regression equation, regression coefficient, correlation coefficient and factor between length and area, breadth and area and product of length and breadth and area of leaf

Leaf parameter	Regression equation ($y = a + bx$)	Regression coefficient (r^2)	Correlation coefficient (r)	Factor (F)
Length versus area	11.98 x – 141.1	0.850	0.922	5.733
Breadth versus area	29.14 x – 81.22	0.911	0.955	17.769
Product of length and breadth versus area	0.743 x + 2.861	0.987	0.994	0.761
Weight of dry leaf versus area	0.218 x +20.71	0.900	0.949	0.268

coefficient value ($r^2 = 0.987$) and the correlation coefficient value ($r = 0.994$) ($p = < 0.01$) clearly showed that there was a significant positive correlation between P and A of a leaf (Fig. 1, Table 1). This suggested the suitability of linear measurement method for determining area of lamina of arrowroot. 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) and Chinese potato (Ravi et al., 2011). The factor (F) derived between product of length and breadth (P) and area of leaf by linear measurement method was 0.761. The regression coefficient (r^2) value observed between P and A was near to 1 indicating that the regression equation was good fit. When the values of leaf area (A) based on leaf factor (F) derived from L, B and P were calculated and matched with the actual value

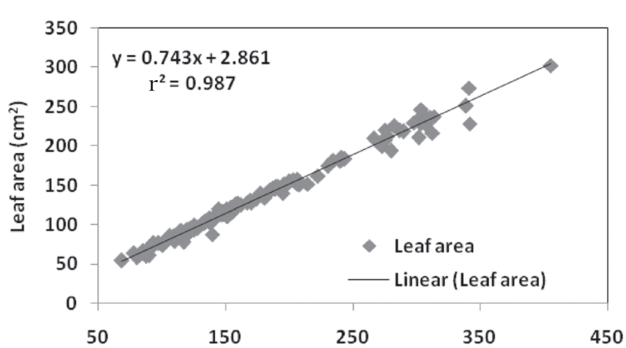

Fig. 1. The linear regression equation and coefficient of determination (r^2) between product of length and breadth (P) of leaf and area (A)

of the leaf area recorded in the leaf area meter, the difference was not significant and was minimum in the case of product of length and breadth (P) of leaf. Therefore, from the F derived for P, total leaf area of arrowroot can be calculated by using the following formula:

Total leaf area = P (average value of few observations) x 0.761 x total number of leaves per plant

Dry leaf weight method

The weight of single dry leaf varied between 162 and 1181 mg and the average weight of dry leaf was 542.12 mg per leaf. The leaf area and weight of dry leaf showed a significant positive correlation coefficient value ($r = 0.949$, significant at $p = < 0.01$), linear association ($Y = 0.218\ x + 20.71$) and coefficient of determination value closer to 1 ($r^2 = 0.900$) (Table 1). This suggested that the dry leaf weight method can also be used for calculating leaf area of arrowroot. The factor (F) derived between dry leaf weight and area of leaflet was 0.268 (Fig. 2, Table 1). From the F value the total leaf area of arrowroot plant can be calculated by the formula:

Total leaf area = Weight of single dry leaf (average of few leaves) x 0.268 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) and Chinese potato (Ravi et al., 2011).

Therefore, comparing the above two methods, the linear measurement method based on P seems to be more feasible for the calculation of leaf area in arrowroot due to positive association between the P and A of leaf. The

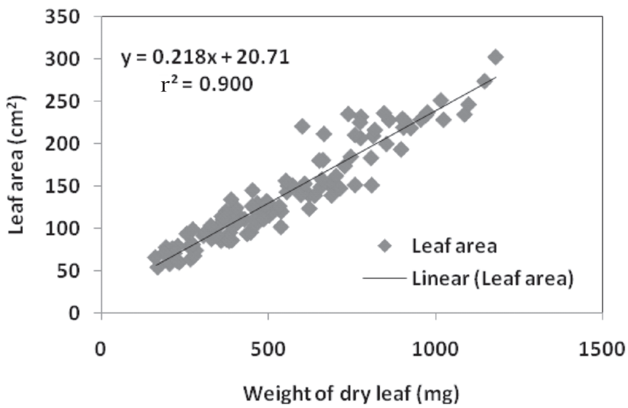

Fig. 2. The linear regression equation and coefficient of determination (r^2) between weight of dry leaf and area (A)

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.

References

Aase, J.K. 1978. Relationship between leaf area and dry matter in winter wheat. *Agron. J.*, **4**: 563-565.

Agueguia, A. 1993. Non-destructive estimation of leaf area in cocoyam (*Xanthosoma sagittifolium* [L.] Schott). *J. Agron. Crop Sci.*, **171**: 138-141.

Ashley, D.A., Doss, B.D. and Bennett, O.C. 1963. A method of determining leaf area in cotton. *Agron. J.*, **55**: 584-585.

Biradar, R.S., Venkateswaralu, T. and Hrishi, N. 1978. Leaf area estimation in *Colocasia*. *J. Root Crops*, **4**: 51-53.

Chapman, T. 1964. A note on the measurement of leaf area of the tannia (*Xanthosoma sagittifolium*). *Trop. Agric.*, **41**: 351-352.

Goenaga, R. and Singh, U. 1996. Estimation of leaf area of taro [*Colocasia esculenta* (L.)] from linear measurement. *J. Agric. Univ. Puerto Rico*. **80**: 183-185.

James George. 1992. Leaf area estimation in dwarf white yam (*Dioscorea rotundata*) by linear measurement method. *J. Root Crops*, **18**: 134 – 135.

Lockard, R.G., Lockard, J.M. and Wounuah, D.D. 1985. A rapid non-destructive method for the estimation of leaf areas in cassava. *Ann. Bot.*, **55**: 125-128.

Lu, H.Y., Lu, C.T., Wei, M.L. and Chan, L.F. 2004. Comparison of different models for non-destructive leaf area estimation in taro. *Agron. J.*, **96**: 448-453.

Nyakwende, E., Paull, C.J. and Atherton, J.G. 1997. Non-destructive determination of leaf area in tomato plants using image processing. *J. Hort. Sci.*, **72**: 255-262.

Palit, P. and Bhattacharyya, A.C. 1984. Measurement of leaf area per plant of white jute (*Corchorus capsularis* L.) and tossa jute (*C. olitorius* L.) using the average specific leaf weight value. *Trop. Agric.*, **61**: 59-62.

Ramanujam, T. and Indira, P. 1978. Linear measurement and weight methods for estimation of leaf area in cassava and sweet potato. *J. Root Crops*, **4**: 47-50.

Ravi, V. and Roy Chowdhury, S. 1989. A method for leaf area determination in *Dioscorea*. *J. Root Crops*, **15**: 45-48.

Ravi, V., James George, Ravindran, C.S., Suja, G., Nedunchezhiyan, M., Byju, G. and Naskar, S.K. 2010. Method for leaf area determination in elephant foot yam. *J. Root Crops*, **36**: 78-82.

Ravi, V., Suja, G. and Ravindran, C.S. 2011. Method for leaf area determination in Chinese potato (*Plectranthus rotundifolius*). *J. Root Crops*, **37**: 37-40.

Venkateswaralu, T. and Biradar, R.S. 1980. Leaf area determination in tannia. *J. Root Crops*, **6**: 45-74.

Villegas, C.D., Bautista, A.T. and Cotejo, F.R. jr. 1981. Accurate and rapid techniques for leaf area measurement in cassava and sweet potato. *Radix*, **3**: 10.

Watson, D.J. 1937. The estimation of leaf area in field crops. *J. Agric. Sci.*, **27**: 474-483.

Watson, D.J. 1952. The physiological variation in field yield. *Adv. Agron.*, **4**: 101-145.