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Estimating the Area of Trifoliolate and Unequally Imparipinnate Leaves of Strawberry

Bernadine C. Strik¹ and John T.A. Proctor²

Department of Horticultural Science, University of Guelph, Guelph, Ontario, Canada, N1G 2W1

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Abstract. Leaflet length and width were used to calculate leaflet area, lateral leaflet area, and trifoliolate area for strawberry, *Fragaria × ananassa* Duch. 'Redcoat' and genotypes 62E55 and 71M59. Using regression analysis, the product of length and width (LW) was chosen as the independent variable. On the basis of predictive ability (R^2) and/or the SE of estimation, the following equations were chosen to determine leaflet area, lateral leaflet area, and trifoliolate area, respectively: $A = 0.66LW + 0.89$; $A = 0.68LW$; $A = 0.69 \sum LW$. A common regression equation could be used for the cultivar and genotypes studied. If the leaf is unequally imparipinnate, then the area of the lateral leaflets and the trifoliolate must be summed to obtain total leaf area.

Growth analysis and the measurement of leaf photosynthetic rates often require a non-destructive method for estimating leaflet area or total leaf area. This method must estimate the area regardless of leaf age, which cannot be judged accurately. The estimation of leaf area by equations involving linear dimensions has been used for crops such as tea (5), medicinal yam (6), ginseng (7), grape (11), safflower (12), and soybean (13). The total area of strawberry leaves has been estimated

by comparing total leaf weight to the weight of leaf disks of known area (2). This time-consuming method is inappropriate for non-destructive measurement of leaf area in the field. Linear measurements have been used to estimate the total area of strawberry leaves (3, 4, 8, 9, 10).³ These areas have been based on linear measurements of either the terminal leaflet or of all 3 leaflets of the trifoliolate. In some strawberry cultivars, however, one or a pair of leaflet(s) is present proximal to the crown, making the leaf unequally imparipinnate (Fig. 1). These leaflets are much smaller than the leaflets of the trifoliolate, but may constitute up to 12% of the total leaf area and thus contribute to the total photosynthetic rate of the leaf ($20.7 \text{ mg CO}_2\text{dm}^{-2} \text{ hr}^{-1}$ for an unequally imparipinnate leaf vs. $18.4 \text{ mg CO}_2\text{dm}^{-2} \text{ hr}^{-1}$ for the trifoliolate alone). To the authors' knowledge, there has been no past work on the use of linear measurements to estimate the area of these leaf-

lets. The lower leaflets (no. 4 in Fig. 1) have a different shape than those of the trifoliolate. Thus, to estimate total leaf area, 2 equations may be required: 1 for the area of the trifoliolate and another for the area of the additional leaflet(s), if present.

The strawberry genotypes 62E55 and 71M59 (from a breeding line developed by W.D. Evans, Univ. of Guelph) and 'Redcoat' were studied. On 10 May 1984, one-year-old plants growing in 12-cm pots were transferred from a lath house to greenhouse. There were 5 plants per genotype, arranged in a randomized complete block design. As suggested by Ackley et al. (1), 25 healthy leaves from each genotype were selected to

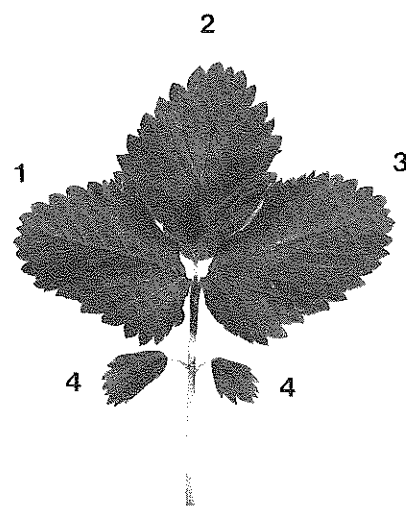


Fig. 1. An unequally imparipinnate strawberry leaf showing the leaflet arrangement. Leaflets of the trifoliolate are numbered consecutively clockwise from the petiole and the lateral leaflets are designated as number 4 for convenience in discussion in the text.

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¹Graduate Student.

²Professor.

Table 1. Relationships between leaflet length, width, and leaflet area for the strawberry genotypes 62E55 and 71M59 and 'Redcoat'.

Variable	Genotype/ cultivar	Regression equation	R ² (%)	SE estimation (cm ²)
Leaflets 1-3 ^z	62E55	A = 0.65LW + 1.07	99.8	0.97
	71M59	A = 0.68LW + 0.75		
	Redcoat	A = 0.65LW + 1.02		
	All ^y	A = 0.66LW + 0.89		
	62E55	A = 0.52L ² + 2.64	99.3	1.68
	71M59	A = 0.59L ² - 0.19		
	Redcoat	A = 0.51L ² + 0.52		
	All	A = 0.56L ² + 0.52		
	62E55	A = 0.72W ² + 1.61	99.4	1.57
	71M59	A = 0.68W ² + 3.46		
	Redcoat	A = 0.77W ² + 2.32		
	All	A = 0.68W ² + 3.33		
Leaflet 4 ^z	62E55	A = 0.66LW + 0.099	96.3	0.25
	62E55	A = 0.68LW	99.1	0.25
	62E55	A = 0.49L ² - 0.21	95.1	0.29
	62E55	A = 0.83W ² + 0.44	90.6	0.41

^zRefer to Fig. 1.

^yRefers to a common regression equation for the cultivar and genotypes studied.

include both young and mature leaves. Of the young leaves selected, the leaflets were unfolded, but not yet fully expanded. To facilitate the recording of data, leaflets of the trifoliolate were numbered clockwise from the petiole (Fig. 1). When present, the lateral leaflet or leaflets were designated as No. 4 (Fig. 1). Although lateral leaflets also may be present on leaves of 71M59 and 'Redcoat', they occur with the greatest frequency on leaves of 62E55. Thus, to estimate the area of leaflet four, 25 leaflets from 62E55 were measured. Leaflet length, width, and area were measured and recorded separately for each leaflet. Maximum length and width were recorded to the nearest 0.1 cm. Leaflet

area was determined with an area meter Model LI-3000 (Lambda Instruments Corporation, Lincoln, Neb.) fitted with a LI-3050A transparent belt accessory. The area meter was calibrated to 0.01 cm² by the manufacturer.

A regression analysis was performed on 2 levels, individual leaflet areas and total leaf area, obtained either by summing the length and width parameters for all leaflets or by leaflet 2 alone. The coefficient of determination, (R²) was calculated for the most commonly used independent variables: length squared (L²), width squared (W²), and their product, LW, with area at the 2 levels (Tables 1 and 2).

When dimensions of different leaflet pa-

rameters were regressed against the leaflet area, there was little difference in predictive ability (R²) between LW, L², and W² (Table 1). When using a common equation for the cultivar and both genotypes, however, the greatest predictive ability and the lowest SE of estimation was found with LW. In all instances, the Y intercept (Y = bX + a) was significantly different from zero, and an equation of the form Y = bX could not be used without a significant loss in predictive ability. A common regression equation relating leaflet LW to area was found for 12 cultivars of soybean (13). Hedge (6) found that the constant varied with the species of yam studied. When considering leaflet 4, the use of L² or LW was comparable in accuracy. The greatest predictive ability was obtained when using LW, assuming a Y intercept equal to zero (Table 1).

Total leaf area was estimated either by multiplying the dimensions of leaflets 1 to 3 and then adding the products or by using the dimensions of leaflet 2 alone. When considering each cultivar and genotype separately, L² and W² had high predictive ability. However, the SE of estimation, 4.03 cm² for L² and 3.46 cm² for W², also was high. With the parameter LW, no accuracy was lost in using a common regression equation for the cultivar and the genotypes (data not shown). Thus, the regression equation for LW (leaflets 1 to 3) with the Y intercept assumed to be zero offered the greatest predictive ability of total leaf area. The SE of estimation for this equation also was quite low (Table 2). The constant b (Y = bX) was less than the 0.78 used by Choma et al. (3).

Using only the terminal leaflet to estimate total leaf area had comparable predictive ability, but the SE of estimation was high when compared to measuring all leaflets (Table 2). The regression equation was similar to that used by Jurik (9). Using just the terminal leaflet has been shown to be less accurate than using all the leaflets to estimate total area in strawberry (4), ginseng (7), and soybean (13). Jurik (9) used only the LW dimensions of the terminal leaflet to estimate the total leaf area of strawberry.

On the basis of the results, the following equations were chosen for the determination of leaflet area (no. 1, 2, or 3), lateral leaflet area (no. 4) and the total leaf area (leaflets 1-3), respectively: A = 0.66LW + 0.89; A = 0.68LW; and A = 0.69ΣLW. A common regression equation could be used for the cultivar and genotypes studied with little loss in predictive ability. If the leaf is unequally imparipinnate, then the area of the lateral leaflets and the 3 leaflets of the trifoliolate must be summed to obtain total leaf area.

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Table 2. Relationships between leaflet length, width, and total leaf area for the strawberry genotypes 62E55 and 71M59 and 'Redcoat'.

Variable	Genotype/ cultivar	Regression equation	R ² (%)	SE estimation (cm ²)
Total Area				
All leaflets ^z	All ^y	A = 0.68ΣLW + 0.89	99.2	1.56
	All	A = 0.69ΣLW	99.9	1.57
62E55	62E55	A = 0.56ΣL ² + 4.69	99.5	4.03
	71M59	A = 0.63ΣL ² - 3.67		
	Redcoat	A = 0.52ΣL ² + 0.26		
	All	A = 0.59ΣL ² - 1.45		
	All	A = 0.59ΣL ² - 1.45		
62E55	62E55	A = 0.74ΣW ² + 2.73	99.7	3.46
	71M59	A = 0.71ΣW ² + 8.14		
	Redcoat	A = 0.83ΣW ² + 4.24		
	All	A = 0.69ΣW ² + 8.76		
	All	A = 0.69ΣW ² + 8.76		
Leaflet 2 ^x	All	A = 1.75LW + 2.93	94.4	4.19
	All	A = 1.84LW	99.5	4.26
62E55	62E55	A = 1.40L ² + 5.72	99.2	5.26
	71M59	A = 1.64L ² - 1.60		
	Redcoat	A = 1.28L ² + 3.76		
	All	A = 1.49L ² + 1.18		
	All	A = 1.49L ² + 1.18		
62E55	62E55	A = 1.87W ² + 7.12	99.1	5.82
	71M59	A = 1.86W ² + 9.45		
	Redcoat	A = 1.95W ² + 8.76		
	All	A = 1.82W ² + 10.16		
	All	A = 1.82W ² + 10.16		

^zThe length and width of leaflets 1-3 (Fig. 1) were multiplied and the products summed.

^yRefers to a common regression equation for the cultivar and genotypes studied.

^xRefers to terminal leaflet of trifoliolate (Fig. 1).

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