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Estimating the Area of Trifoliolate and Unequally Imparipinnate Leaves of Strawberry

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Additional index words. *Fragaria* ×*ananassa*, linear measurements

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 ΣLW. 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 nondestructive 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 nondestructive 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). 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 mg $CO_2dm^{-2}hr^{-1}$ for an unequally imparipinnate leaf vs. 18.4 mg$CO_2dm^{-2}hr^{-1}$ 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 leaflets. 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

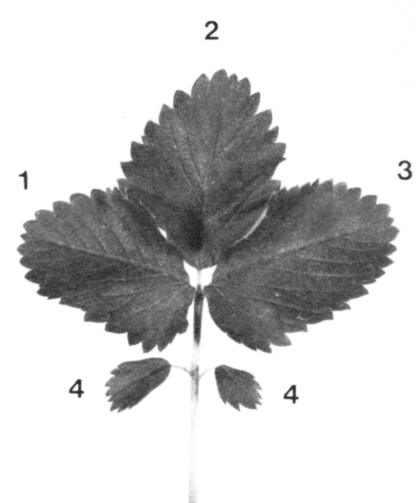

Fig. 1. An unequally imparipinnate strawberry leaf showing the leaflet arrangement. Leaflets of the trifoliolate are numbered consecutively clockwise from the petiole and the lateral leaflets are designated as number 4 for convenience in discussion in the text.

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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		
	71M59	A = 0.68LW + 0.75	99.8	0.97
	Redcoat	A = 0.65LW + 1.02		
	All[y]	A = 0.66LW + 0.89	97.4	0.99
	62E55	A = $0.52L^2$ + 2.64		
	71M59	A = $0.59L^2$ − 0.19	99.3	1.68
	Redcoat	A = $0.51L^2$ + 0.52		
	All	A = $0.56L^2$ + 0.52	88.8	2.05
	62E55	A = $0.72W^2$ + 1.61		
	71M59	A = $0.68W^2$ + 3.46	99.4	1.57
	Redcoat	A = $0.77W^2$ + 2.32		
	All	A = $0.68W^2$ + 3.33	92.4	1.69
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

[z]Refer to Fig. 1.
[y]Refers 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 cm^2 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, (R^2) was calculated for the most commonly used independent variables: length squared (L^2), width squared (W^2), and their product, LW, with area at the 2 levels (Tables 1 and 2).

When dimensions of different leaflet parameters were regressed against the leaflet area, there was little difference in predictive ability (R^2) between LW, L^2, and W^2 (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 L^2 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, L^2 and W^2 had high predictive ability. However, the SE of estimation, 4.03 cm^2 for L^2 and 3.46 cm^2 for W^2, 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 = 0.69 ΣLW. 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.

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	A = $0.56\Sigma L^2$ + 4.69		
	71M59	A = $0.63\Sigma L^2$ − 3.67	99.5	4.03
	Redcoat	A = $0.52\Sigma L^2$ + 0.26		
	All	A = $0.59\Sigma L^2$ − 1.45	91.2	5.24
	62E55	A = $0.74\Sigma W^2$ + 2.73		
	71M59	A = $0.71\Sigma W^2$ + 8.14	99.7	3.46
	Redcoat	A = $0.83\Sigma W^2$ + 4.24		
	All	A = $0.69\Sigma W^2$ + 8.76	94.7	4.06
Leaflet 2[x]	All	A = 1.75LW + 2.93	94.4	4.19
	All	A = 1.84LW	99.5	4.26
	62E55	A = $1.40L^2$ + 5.72		
	71M59	A = $1.64L^2$ − 1.60	99.2	5.26
	Redcoat	A = $1.28L^2$ + 3.76		
	All	A = $1.49L^2$ + 1.18	88.0	6.11
	62E55	A = $1.87W^2$ + 7.12		
	71M59	A = $1.86W^2$ + 9.45	99.1	5.82
	Redcoat	A = $1.95W^2$ + 8.76		
	All	A = $1.82W^2$ + 10.16	89.1	5.81

[z]The length and width of leaflets 1–3 (Fig. 1) were multiplied and the products summed.
[y]Refers to a common regression equation for the cultivar and genotypes studied.
[x]Refers to terminal leaflet of trifoliolate (Fig. 1).

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Tolerance of Highbush and Rabbiteye Blueberry Cultivars to Hexazinone

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Additional index words. *Vaccinium corymbosum*, *V. ashei*, soil organic matter, Velpar, soil type, herbicide

Abstract. **Hexazinone was applied as a soil drench to 1-year-old rooted hardwood cuttings of highbush (*Vaccinium corymbosum* L.) and rabbiteye (*V. ashei* Reade) blueberries in a series of greenhouse experiments. No differences in susceptibility to hexazinone were detected among 10 highbush and 3 rabbiteye cultivars growing in a fine sand soil. Two highbush and 2 rabbiteye cultivars were assayed for hexazinone tolerance in low, medium, and high organic matter soil which contained 1.3%, 3.5%, and 49.5% organic matter, respectively. Hexazinone at 1 or 2 kg/ha had no inhibitory effect on blueberry growth in the high organic matter soil, inhibited growth slightly on the medium organic matter soil and caused severe injury in the low organic matter soil. At rates of 4 and 8 kg/ha, injury was severe on the medium and low organic matter soils but very slight on the high organic matter soil.**

Hexazinone [3-cyclohexyl-6-(dimethylamino)-1-methyl-1,3,5-triazine-2,4(1*H*,3*H*)-dione] is a symmetrical triazine herbicide that controls many weeds not controlled by herbicides presently used in weed management programs for blueberries (1). Hexazinone has been reported to control weeds in lowbush blueberries better than simazine (6-chloro-*N*,*N*-diethyl-1,3,5-triazine-2,4-diamine), atrazine [6-chloro-*N*-ethyl-*N*-(1-methylethyl)-1,3,5-trazine-2,4 diamine], terbacil [5-chloro-3-(1,1-dimethylethyl)-6-methyl-2,4(1*H*,3*H*)pyrimidinedione], and diuron [N-(3,4-dichlorophenyl)-*N*,*N*-dimethylurea] (5).

Blueberries appear tolerant to soil applied hexazinone. James (3) in New Zealand, reported that applications of hexazinone at rates of 2 to 16 kg/ha on a peat soil had no adverse effect on highbush fruit production and caused a significant reduction in weed dry matter accumulation. However, greenhouse studies have shown that some highbush cultivars are sensitive to the soil applied hexazinone (4). Application of 1 to 3 kg/ha of hexazinone to the soil of dormant 3-year-old highbush 'Berkeley' caused interveinal chlorosis at the 1 kg/ha rate and severe foliar necrosis at the 2 and 3 kg/ha rate. Applications to 'Bluecrop' resulted in minor injury at 1 kg/ha, interveinal chlorosis at 2 kg/ha, and variable damage ranging from no effect to death at 3 kg/ha (4). In addition, applications of the herbicide directly to foliage of lowbush blueberries can cause considerable damage (2). Blueberry plants can tolerant hexazinone without yield reduction only if the herbicide is applied when the plants are dormant, or if application of the herbicide is directed to the base of the plant avoiding contact with foliage.

Two greenhouse experiments were conducted during 1983 at the North Carolina State Univ. Horticultural Science greenhouses to determine the influence of hexazinone rate and soil type on blueberry cultivar tolerance. Plant material consisted of 1-year-old rooted hardwood cuttings of highbush 'Angola', 'Bluechip', 'Bluecrop', 'Blueray', 'Croatan', 'Earliblue', 'Harrison', 'Jersey', 'Murphy', and 'Wolcott' and rabbiteye cultivars 'Powderblue', 'Premier', and 'Tifblue'. Plants were held in cold storage for 6 weeks at 1°C to satisfy chilling requirement before they were planted individually in 15 cm diameter pots containing a Lynn Haven fine sand soil with a pH of 4.1 and an organic matter content of 3.5%.

The dormant blueberry plants were placed in a 24°C day, 18° night greenhouse on 9 Mar. 1983. Immediately after leaf budbreak, 50 ml of hexazinone solutions, equivalent to rates of 0, 1, 2, 4, or 8 kg/ha were added as a soil drench. Plants were randomized in a complete block design with 4 replications and 1 plant per replication. Plants were watered as needed, and a commercial water soluble fertilizer (20.0 N–9.1P–16.6 K) was applied every 2 weeks. Seventy-five days after her-

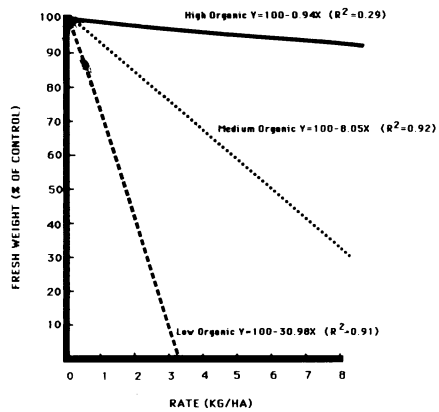

Fig. 1. Influence of soil organic matter content and hexazinone activity on fresh weight of blueberry (expressed as percentage of control).

Table 1. Correlation of several growth parameters of blueberry cuttings with fresh weight when plants were treated with 5 rates of hexazinone.

Parameter	*r*
Shoot length (cm)	0.97
Leaf area (cm^2)	0.97
Leaf number	0.99
Dry weight (g)	0.99

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