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Mathematical Constants for Non-Destructive Rapid Method of Leaf Area Determination in Mulberry (*Morus* spp.)

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Mathematical constants for multiplication with leaf length (l) or breadth (b) or l × b have been worked out for determining leaf area in promising mulberry genotypes *viz.*, Chinese White, S-146, Chak Majra and Sujanpur Local of sub-tropical India. When pooled, the mathematical constants worked out were 8.1132, 10.1019 and 0.5992 for multiplication with leaf length, breadth and l × b, respectively, for genotypes bearing un-lobbed leaves and 6.9447, 8.2761 and 0.5009 for multiplication with leaf length, breadth and l × b, respectively for genotypes bearing lobbed leaves. Leaf area can be worked out by using any constant by multiplying either with leaf length or breadth or both (l × b). Estimated leaf areas worked out were found significantly and positively correlated with actual leaf area (r = 999). The suggested present non-destructive method by using mathematical constants is very quick and alternative to electronic leaf area meter for spot leaf area determination in mulberry which is the only food source for mulberry silkworm in sericulture industry.**

Key words: Mulberry (*Morus* spp.), Leaf area determination, Mathematical constants, Rapid non-destructive method

Introduction

The mulberry (*Morus* sp.) leaf is the sole food source for rearing of silkworms (*Bombyx mori* L.) in sericulture industry. In India, silk productivity per unit of area is very low as compared to China, which is mainly due to poor yielding mulberry genotypes. The economy or profitability of sericulture depends primarily on yield and quality of the mulberry leaf produced. Various studies on silkworm's nutrition have established the role of leaf quality on growth and development of the silkworm and its importance in overall silk production (Shankar *et al.*, 1994; Singhal *et al.*, 1998a, b; 1999a, b; 2001; Singhal and Mala, 1998; Subburathinam *et al.*, 1993; Subburathinam and Chetty, 1991). Thus, for improvement in overall silk production, there is an urge to develop more productive mulberry genotypes with superior leaf quality which contributes as high as 38.2% in getting successful silkworm cocoon crop than the climate (37.0%), rearing technique (9.3%), silkworm race (4.2%), silkworm eggs (3.1%) and other factors (8.2%) (Miyashita, 1986).

In mulberry, leaf is the desired organ for sericulture which plays an important role in the photosynthetic activity of the plant and leaf area is considered as a reliable index for determining the overall metabolic efficiency (Singhal *et al.*, 2000). For all mulberry improvement programmes, leaf area is the most desired parameter to be measured at various stages of plant growth without plucking of leaf for selection of improved genotypes in breeding programmes.

At most of the research stations, portable leaf area meter is not available due to non-affordable cost and it has become utmost necessary to devise some alternative non-destructive method for leaf area determination in mulberry under sub-tropical condition of Jammu province where lot of mulberry wealth is available to explore for developing more productive genotypes by breeding techniques, so that the bivoltine sericulture industry of this province can

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be made more profitable with superior quality of silk.

Non-destructive methods of leaf area determination by using factor are found successful in many agricultural crops like Cocoyam (Agueguta, 1993), Linseed (Dixit *et al.,* 1982), Maize (Francis *et al.*, 1969), Brinjal (Mohammad and Krishnamurthy, 2001), Cotton, Green gram and Groundnut (Musande *et al.*, 1982), Opium Poppy (Nigam *et al.,* 1987), Asgandh (Patidar *et al.,* 1990), Sorghum (Stellers *et al.,* 1981). In the present investigation, mathematical constants were devised for non-destructive method of leaf area determination in mulberry and estimated leaf area obtained by applying such constants were also tested for accuracy by regression models and single constants.

Materials and Methods

The present study was carried out at mulberry farm of Regional Sericultural Research Station, Miran Sahib, Jammu, India situated at the latitude and longitudes of 32.0 17' and 73.0 26', respectively. The mulberry plants were grown under bush type of plantation with 3' × 3' spacing in between the plants and rows. From three years old plantations, all the leaves of 10 random plants of different plant populations from four most promising mulberry genotypes, namely, Chinese White, S-146, Chak Majra and Sujanpur Local, were sampled. Actual leaf area (LAA) of all the leaves was measured by computerized Licor leaf area meter. Apparent leaf area (LAP) was calculated by multiplying leaf length x breadth at maximum. The mathematical constant (C) was worked out by the formula C = LAA/LAP. Similarly, in all the four genotypes, single constants were also worked out for multiplying them either with leaf length (l) or breadth (b) by dividing actual leaf area with leaf length or breadth for finding out estimated leaf area (ALE). Deviations from actual leaf area were calculated and significance was tested by paired t-test. To minimize the error of independent variables, *viz.,* the linear measurement of leaf length, breadth and l × b, were regressed on the dependent variable - actual leaf area. The best fit curve was chosen and the linear regression model of the form y = a + b x was found appropriate. Simple constants were also determined as the coefficient of actual yield area and leaf length, breadth or l × b. The leaf area was estimated by employing the regression model and the simple co-efficients for total leaves. The accuracy of each method was detected by employing paired t-test in comparison with actual leaf area (Zaman *et al.*, 1982). Data of three genotypes (Chinese White, S-146 and Chak Majra) bearing un-lobbed leaves were finally pooled and three constants for leaf length, breadth and l × b were worked out. Similarly, data of different plant populations of the genotype Sujanpur local bearing lobbed leaves, were also pooled and three constants were worked out. Any constant depending upon the leaf length or breadth or l × b can be employed for leaf area determination. Deviation from actual leaf area was calculated and significance was tested by paired 't' test. Correlation coefficient and regression equations were also worked out.

Results

The regression model developed through each of the three leaf variables and their respective coefficients of determination in four genotypes are presented in Table 1, 2, 3, 4. The mathematical relationship of leaf area estimation through leaf length, breadth and l × b through linear

Table 1. Regression equations for leaf area estimation of mulberry (*Morus* sp.), genotype-Chinese white, through leaf variables

Variancer	Regression equation			
	r	a	b	r^2
Length	0.97	−98.48	13.43	0.94
Breadth	0.97	−96.73	17.53	0.94
Length (l) × Breadth (b)	0.99	0.40	0.59	0.98

Table 2. Regression equations for leaf area estimation of mulberry (*Morus* sp.), genotype-S-146, through leaf variables

Variancer	Regression equation			
	r	a	b	r^2
Length	0.94	−99.92	14.64	0.88
Breadth	0.64	−108.32	17.78	0.40
Length (l) × Breadth (b)	0.86	3.85	0.58	0.73

Table 3. Regression equations for leaf area estimation of mulberry (*Morus* sp.), genotype-Chak Majra, through leaf variables

Variancer	Regression equation			
	r	a	b	r^2
Length	0.93	−83.86	13.17	0.86
Breadth	0.93	−103.21	17.77	0.86
Length (l) × Breadth (b)	0.99	−0.33	0.60	0.98

Table 4. Regression equations for leaf area estimation of mulberry (*Morus* sp.), genotype-Sujanpur local, through leaf variables

Variancer	Regression equation			
	r	a	b	r^2
Length	0.96	−163.22	17.08	0.92
Breadth	0.97	−68.75	13.35	0.94
Length (l) × Breadth (b)	0.97	−6.43	0.47	0.94

Table 5. Estimated leaf area of mulberry (*Morus* sp.), genotype-Chinese white, by different methods and their comparative test with actual leaf area

Method		Leaf area (cm^2)	Paired t-test
1. Actual leaf area on computerized electronic leaf area meter (cm^2)		110.61	
2. *Estimated leaf area (cm^2)* by regression models			
a. leaf length (l)		110.54	0.01
b. leaf breadth (b)		110.47	0.03
c. Leaf length × breadth (l × b)		110.65	0.008
3. Estimated leaf area (cm^2) by single constants	Constants		
a. leaf length (l)	7.1068	110.59	0.005
b. leaf breadth (b)	9.3579	110.58	0.007
c. Leaf length × breadth (l × b)	0.5919	110.44	0.020

Table 6. Estimated leaf area of mulberry (*Morus* sp.), genotype-S-146, by different methods and their comparative test with actual leaf area

Method		Leaf area (cm^2)	Paired t-test
1. Actual leaf area on computerized electronic leaf area meter (cm^2)		158.06	
2. Estimated leaf area (cm^2) by regression models			
a. leaf length (l)		157.89	0.04
b. leaf breadth (b)		154.46	0.93
c. Leaf length × breadth (l × b)		155.93	0.40
3. Estimated leaf area (cm^2) by single constants	Constants		
a. leaf length (l)	8.9756	157.85	0.05
b. leaf breadth (b)	10.6884	157.85	0.20
c. Leaf length × breadth (l × b)	0.6028	157.33	0.14

Table 7. Estimated leaf area of mulberry (*Morus* sp.), genotype-Chak Majra, by different methods and their comparative test with actual leaf area

Method		Leaf area (cm^2)	Paired t-test
1. Actual leaf area on Computerized electronic Leaf area meter (cm^2)		135.64	
2. Estimated leaf area (cm^2) by regression models			
a. leaf length (l)		135.42	0.05
b. leaf breadth (b)		135.44	0.05
c. Leaf length × breadth (l × b)		135.04	0.11
3. Estimated leaf area (cm^2) by single constants	Constants		
a. leaf length (l)	8.1426	135.62	0.005
b. leaf breadth (b)	10.0968	135.62	0.005
c. Leaf length × breadth (l × b)	0.6012	135.60	0.007

Table 8. Estimated leaf area of mulberry (*Morus* sp.), genotype-Sujanpur Local, by different methods and their comparative test with actual leaf area

Method		Leaf area (cm^2)	Paired t-test
Actual leaf area on computerized electronic leaf area meter (cm^2)		118.81	
2. Estimated leaf area (cm^2) by regression models			
a. leaf length (l)		111.76	0.009
b. leaf breadth (b)		111.60	0.030
c. Leaf length × breadth (l × b)		111.36	0.050
3. Estimated leaf area (cm^2) by single constants	Constants		
a. leaf length (l)	6.9447	111.73	0.010
b. leaf breadth (b)	8.27614	111.72	0.010
c. Leaf length × breadth (l × b)	0.5007	111.81	0.010

regression models were found to have a positive and highly significant correlation with actual leaf area determined through computerized leaf area meter. The mean leaf area estimated by regression models and simple coefficients and test of significance through paired t-test values in all four genotypes are presented in Table 5, 6, 7, 8. The results indicated that the leaf area estimated by employing the linear regression model through the measurement of leaf length, breadth and l × b was 110.54, 110.47 and 110.65 sq. cm. in the genotype Chinese White; 157.89, 154.46 and 155.93 sq. cm. in the genotype S-146; 135.42, 135.44 and 135.04 sq. cm. in the genotype Chak Majra and 111.76, 111.60 and 111.36 sq. cm. in the genotype Sujanpur Local. These estimates were close to the actual leaf area of 110.61, 158.06, 135.64 and 111.81 sq. cm. in the genotypes Chinese White, S-146, Chak Majra and Sujanpur Local, respectively as indicated by non significant differences by paired t-test value. The multiplication of leaf length by the constant 7.1068, breadth by 9.3579 and l × b by 0.5919 revealed mean estimated leaf areas of 110.59, 110.58 and 110.44 sq. cm. in the genotype Chinese White (Table 5). Similarly, the constants for length, breadth and l × b for all three other genotypes have also shown the estimated leaf areas significantly closer to the actual leaf area measured by the computerized leaf area meter (Table 6 to 8). The paired t-test values con-

Table 9. Pooled analysis for estimated leaf area in promising mulberry genotypes bearing un-lobbed leaves

Mulberry genotype	Leaf area			
	Actual	Apparent	Estimated	Deviation from actual
Chinese White	110.61	186.87	111.97	1.36
S-146	158.06	262.22	157.12	–0.94
Chak Majra	135.64	225.62	135.20	–0.44
Pooled over all the 3 genotypes	134.77	224.90	134.76	–0.01

Constants

Length (l) = 8.1132
Breadth (b) = 10.1019
l × b = 0.5992

Correlation coefficient (r) = 0.999**

't' value = 0.004

Linear regression equation : Y = a + bx
= 6.586 + 0.951x

Table 10. Pooled analysis for estimated leaf area from different plant populations of promising mulberry genotype- sujanpur local bearing lobbed leaves

Mulberry genotype	Leaf area			
	Actual	Apparent	Estimated	Deviation from actual
Sujanpur local	111.81	223.22	111.77	–0.04

Constants

Length (l) = 6.9447
Breadth (b) = 8.2761
l × b = 0.5009

Correlation coefficient (r) = 0.999**

't' value = 0.008

Linear regression equation: Y = a + bx
= 7.07 + 0.994x

firmed that the leaf areas estimated by these methods were not significantly different from the actual leaf areas. The data collected for three genotypes (Chinese White, S-146 and Chak Majra) were pooled and constants for leaf length (8.1132), breadth (10.1019) and l × b (0.5992) were worked out for genotypes bearing un-lobbed leaves (Table 9). The constants of 6.9447, 8.2761 and 0.5009 for multiplication of leaf length, breadth and l × b, respectively were also worked out from pooled data of ten different plant populations of mulberry genotype Sujanpur Local bearing lobbed leaves (Table 10). Actual leaf area was found significantly and positively co-rrelated with estimated leaf area of un-lobbed and lobbed genotypes (r = 0.999**). The utility of these single mathematical constants to be multiplied with only leaf length or breadth or l × b in determining leaf area in either un-lobbed or lobbed mulberry genotypes is very easy and quick as well as non-destructive.

Discussion

Reddy (1999) has screened the mulberry genotypes Mysore local, M-5, S-36, S-54, S-34, MR-2, DD-1 of tropical India and advocated the correction factors of 0.54, 0.67, 0.72, 0.72, 0.60, 0.66 and 0.75 for respective genotypes. Mean correction factor found was 0.69 and further reported that such correction factors should only be used for a specific leaf in the branch to calculate the total leaf area of a plant. This method may not be found applicable, as, depending on the study, area needs to be found out for any desired leaf and not for the specific leaf. Moreover, specific correction factor for the individual genotype highly restricts its application. It is reported here that the single mathematical constants for length or breadth or l × b worked out in the present study can safely be employed for determining leaf area of any un-lobbed or lobbed mulberry genotype of sub-tropical India as evidenced by non significant differences in actual and the estimated leaf areas. These constants even can be tried in genotypes of other eco-climatic zones for their applicability in leaf area determination of mulberry for widely using them for mulberry improvement programmes.

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References

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

Dixit, P. K., C. S. Dubey and J. P. Sharma (1982) Note on the estimation of leaf area in linseed. *Indian J. Agric. Sci.* **52**, 396-397.

Francis, C. A., J. N. Rutger and A. F. E. Palmer (1969) A rapid method for plant leaf area estimation in maize (*Zeamays* L.). *Crop Sci.* **9**, 537-539.

Miyashita, V. (1986) A report on mulberry cultivation and training methods suitable to bivoltine rearing in Karnataka, Central Silk Board, India, pp. 1-7.

Mohammad, S. and R. Krishnamurthy (2001) Simple and indirect method of leaf area measurement in brinjal (*Solanum melongena* L.). *Res. Crops* **2**, 51-53.

Musande, V. G., V. D. Sondge, B. N. Chavan and D. N. Borulkar (1982) Leaf area constant for cotton, greengram, blackgram and groundnut. *Indian J. Agric. Sci.* **52**, 573-575.

Nigam, K. B., L. S. Kahar and G. K. Saxena (1987) Estimation of leaf area in opium poppy. *Indian J. Agric. Sci.* **57**, 604-605.

Patidar, H., V. S. Kandalkar and Smita Nigam (1990) Estimation of leaf area in asgandh (*Withania somnifera*). *Indian J. Agric. Sci.* **60**, 263-264.

Reddy, Nanja Y. A., Sarla Kumari and C. V. Venkatesh Murthy (1999) Non-destructive method for rapid estimation of leaf area in mulberry; in *Moriculture in Tropics.* Vol. 1, pp. 64-67, Proc. National Seminar on Tropical Sericulture, UAS, Bangalore, India.

Shankar, M. A., K. Shivashankar and M. C. Devaiah (1994) Effect of feeding mulberry leaves deficient in secondary nutrients on larval growth, development, cocoon weight and silk quality. *Sericologia* **34**, 511-518.

Singhal, B. K., S. Chakraborti, V. R. Mala, A. Sarkar and R. K. Datta (2000) Photosynthesis for crop improvement in mulberry (*Morus* spp.). *Sericologia* **40**, 27-55.

Singhal, B. K., A. Dhar, S. M. H. Qadri and M. M. Ahsan (2001) Mulberry nutrition for development of sericulture in Jammu & Kashmir. *Asian Text. J.* **10**, 35-42.

Singhal, B. K. and V. R. Mala (1998a) An insight into silkworms food. *Indian Text. J.* **108**, 86-88.

Singhal, B. K., V. R. Mala and V. Kumar (1998b) Indian mulberry sericulture- Problems & Prospects. *Modern Text. J.* **4,** 27-35.

Singhal, B. K., V. R. Mala and S. Chakraborti (1999a) Nutritional disorders of mulberry (*Morus* spp.) I. Physiological and biochemical changes under deficiency. *Philippine J. Sci.* **128**, 161-170.

Singhal, B. K., V. R. Mala, A. Sarkar and R. K. Datta (1999b) Nutritional disorders of mulberry (*Morus* spp.) III. Leaf nutrient guide for secondary nutrients. *Sericologia* **39**, 599-609.

Stellers, F. C., S. Weardan and A. W. Pauli (1981) Leaf area estimation in grain sorghum. *Agron. J.* **53**, 187-188.

Subburathinam, K. M. and J. Sulochana Chetty (1991) Effect of fortification of mulberry leaves with minerals to silkworms, *Bombyx mori* L. *Indian J. Seric.* **30**, 121-123.

Subburathinam, K. M., M. Krishnan and J. Sulochana Chetty (1993) Effects of minerals on the bioenergetics of the silkworms *Bombyx mori. Sericologia* **33**, 509-514.

Zaman, S. M. H., R. Kamal and H. McIntosh (1982) Simple lessons from Biometry. Bangladesh Rice Research Institute, Dhacca.