Linear models for leaf area measurement from small leaflets of multipurpose trees of arid to semi-arid area

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Abstract: *Leaf area is a determinant of plant productivity, transpiration, development rate. It is also useful for the analysis of canopy architecture. That' s why accurate measurement of leaf area required for the specific research. In this study, tiny leaves of A. nilotica, L. leucocephala, P. juliflora were measured with the Leaf Area Meter software. This method is accurate and rapid. Comparisons between conventional method and LAM software method is done by using the leaves of D. latifolia. Then, growth analysis was done.*

Key Words: *leaf area, LAM, A. nilotica, L. leucocephala, P. juliflora*

1. INTRODUCTION:

Leaf area is a key variable in study of physiology, horticulture and crop science (1) (2). It is a one of the major parameters in plant modeling studies and thus the most important parameter to develop physiological model in plant breeding (3). It plays an important role to determine productivity, development rate, yield potential, radiation use efficiency and water as well as nutrient takes up (4). Rates of canopy, gas exchange and energy balance are also affected by leaf area (5) (6). The leaf area measurement of the leaves of three tree species *A. nilotica, L. leucocephala and P. juliflora* is very difficult due to their small leaf size, however, they are multipurpose trees and of great economic importance.

2. LITERATURE REVIEW:

Leaf area is a core element of ecological field and modeling studies (7). Many workers have demonstrated the importance of it in various studies. In plant pathology to compare the effect of different diseases on plant types may use leaf area as an indicator of treatment effectiveness (8). It is also required to determine evapotranspiration of forest (9). It is used in the monitoring of phytomass production and grain yield of cereal crops (10). To understand rates of energy and materials exchange between forest and atmosphere, leaf area is a key variable. Change in the leaf area may be useful for estimating crop growth.

It also useful for analysis of canopy architecture as it allows the determination of leaf area. Thus accurate measurements of leaf area are essential for understanding the interaction between crop growth and its environment. Many methods have been developed to measure the leaf area which includes drawing, blueprinting, photographing, and image analysis (11). These processes are time consuming and facilities are generally expensive for the measurements. Therefore, another simple, inexpensive, rapid, reliable and non-destructive method of estimating leaf area is required for the experiments (3).

Estimation of leaf area from equations using simple measurement of leaf dimension is an alternative to serve the purpose (12).

3. STUDY OBJECTIVES:

In this study, four species from Fabaceae family are taken; viz. *Acacia nilotica, Leuceana leucocephala, Prosopis juliflora* and *Dalbergia sissoo* for the leaf area measurements. The main objective of this study is to find out regression equation for leaf area of these species, using non - destructive method.

4. MATERIALS:

Material collection:

In this study, four plant species were studied for leaf area measurement and to find out regression growth constant of the leaf. 1) *Acacia nilotica,* 2) *Leucaena leucocephala,* 3) *Prosopis juliflora* and *4) Dalbergia latifolia* plant species are studied. Leaves were collected from the botanical garden of Department of Biosciences, Saurashtra University, Rajkot. In this study, 60 leaves of different sizes were taken from each species.

5. METHOD:

Measurement of leaf area:

Leaves were washed thoroughly under running tap water. Then they are bloated on filter paper. Small leaflets separated from the petiole and midrib were scanned together in 72×72 psi resolution and saved as .bmp file. Individual leaf area was measured by using Leaf Area Meter software.

6. DISCUSSION:

Estimation of leaf area from the plant species gives more insight it to understand the physiology and ecology of the plant, canopy structure and function and the plant system as a whole. In this study, the experiment is divided into two parts. In the first part of the study an attempt is made to measure leaf area from plants such as *A. nilotica, L. leucocephala, P. juliflora* which are technically difficult using standard conventional method. Even leaf area meter also become limiting in a number of the occasions when these plants demonstrate it sleeping movement/folding movement. However, we could do it accurately and precisely due to the high sensitivity of the software at a pixel level. In the second part of the experiment, a plant species i.e. *D. latifolia* is used. The leaves of this plant can be drawn on graph paper for length and width dimensions. To avoid personal bias, two volunteers are also requested to judge the efficiency of the software and to compare and contrast time taken, sensitivity and accuracy of the software.

7. ANALYSIS:

Growth analysis:

Fresh weight was taken of individual leaf. All leaves were kept in oven at 65ºC for 48 hrs and dry weight was measured. The difference of fresh weight and dry weight was considered as water content.

Statistical analysis:

Leaf area obtained using LAM software is calculated to derive constant against leaf dry weight.

9. RESULT:

Acacia nilotica:

In *A. nilotica*, plant leaf area ranged from 2.659 cm^2 to 63.598 (Table 2) cm^2 from 60 leaves. Fresh weight data ranged from 31.5 mg/leaf to 411.6 mg/leaf (Table 2) and water content ranged from 11.8 mg/leaf to 213.1 mg/leaf (Table 2) The $R^2 = 0.823$ reported for dry weight (Fig. 1) The regression equation, $y = 5.309x + 18.17$ was used to find out leaf area (Fig. 1) Similarly, data on water content derived as difference between fresh weight and dry weight showed $R^2 = 0.742$ (Fig. 1) The regression equation, $y = 3.342x+30.75$ was obtained (Fig. 2) The R^2 value of dry weight was more significant than water content.

Leucaena leucocephala:

In *L. leucocephala*, plant leaf area ranged from 4.624 cm^2 to 75.472 cm^2 from 60 leaves. Fresh weight data ranged from 45.8 mg/leaf to 1366.1 mg/leaf and water content ranged from 30.3 mg/leaf to 1014.9 mg/leaf (Table 3). The $R^2 = 0.810$ reported for dry weight. The regression equation, $y = 5.439x + 9.416$ was used to find out leaf area (Fig. 3). The $R^2 = 0.809$ reported for water content. The regression equation, $y = 8.408x - 6.104$ was obtained (Fig. 4).

Prosopis juliflora:

In *P. juliflora* plant leaf area ranged from 12.886 cm^2 to 43.874 cm^2 from 60 leaves. Fresh weight data ranged from 181.8 mg/leaf to 587.7 mg/leaf and water content ranged from 85.9 mg/leaf to 365.4 mg/leaf (Table 4). The $R^2 = 0.805$ reported for dry weight. The regression equation, $y = 5.0x + 31.54$ was used to find leaf area (Fig. 5). The $R^2 = 0.805$ reported for water content. The regression equation, $y = 8.233x + 15.48$ was obtained (Fig. 6).

Dalbergia latifolia:

In *D. latifolia* plant leaf area ranged from 4.573 cm^2 to 41.891 cm^2 from 60 leaves. Fresh weight data ranged from 21.1 mg/leaf to 703.8 mg/leaf and water content ranged from 9.5 mg/leaf to 413 mg/leaf (Table 5). The $R^2 = 0.936$ reported for dry weight. The regression equation, $y = 6.367x + 0.611$ was used to find leaf area (Fig. 7). The $R^2 = 0.909$ reported for water content. The regression equation, $y = 10.01x - 30.14$ was obtained (Fig. 8).

11. CONCLUSION:

In this study, dry weight and water content showed statistically significant relationship with leaf area. Overall data suggest that the software measurement is more accurate and rapid. The data can archive in the computer and can be studied as and when needed. Water content and dry weight are good parameters for linear model development.

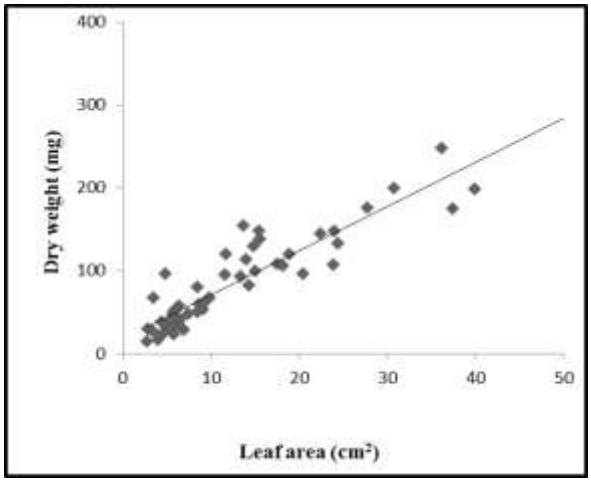

Fig.1 Relationship between dry matter and leaf area in *Acacia nilotica* (N = 60, Y=5.309x + 18.47, R^2 = 0.823, P<0.001)

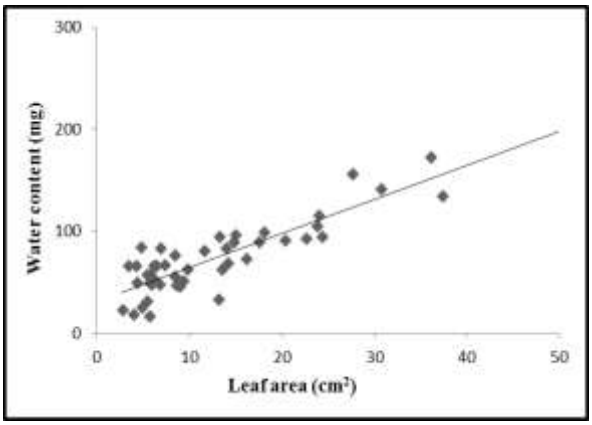

Fig.2 Relationship between water content and leaf area in *A. nilotica* (N=60, Y=3.342x + 30.75, R^2 = 0.742, P<0.001)

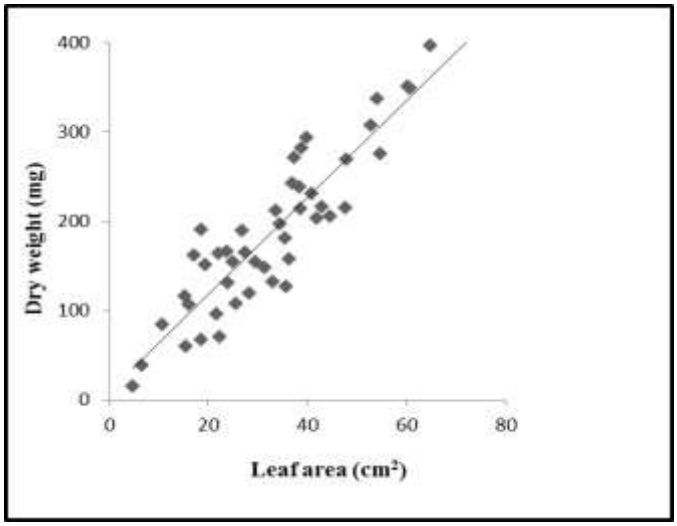

Fig.3 Relationship between dry weight and leaf area in *Leucaena leucocephala* (N=60,Y== 5.439x + 9.416,R^2 = 0.810,P<0.001)

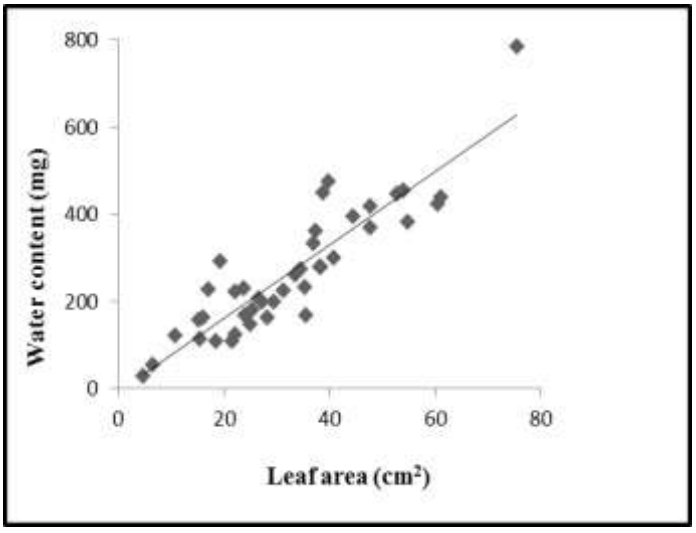

Fig.4 Relationship between water content and leaf area in *Leucaena leucocephala* (N = 60, Y = 8.408x – 6.104, R^2 = 0.809, P<0.001)

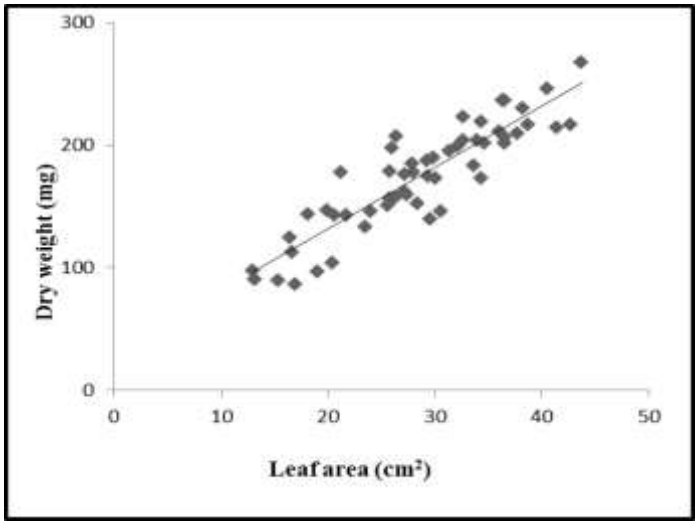

Fig.5 Relationship between Dry weight and Leaf area in *Prosopis juliflora* (N=60,Y=5.000x + 31.54,R^2 = 0.805,P<0.001)

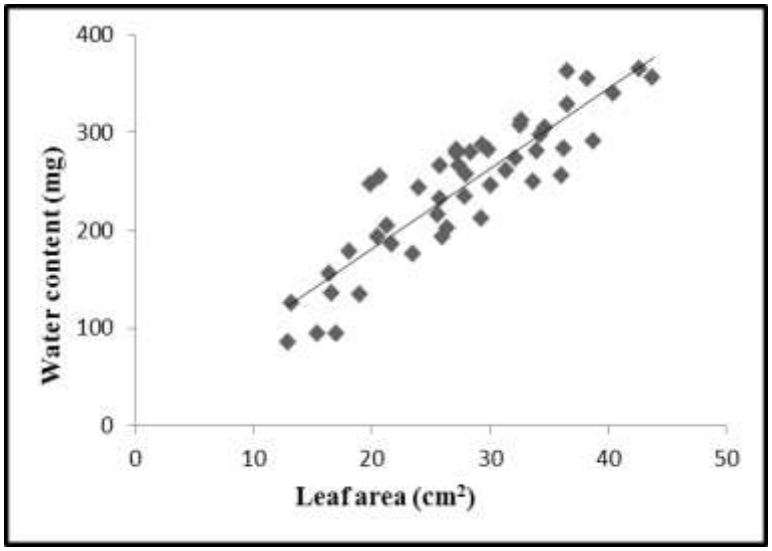

Fig.6 Relationship between Water content and Leaf area in *Prosopis juliflora* (N=60,Y=8.233x + 15.48,R^2 = 0.805,P<0.001)

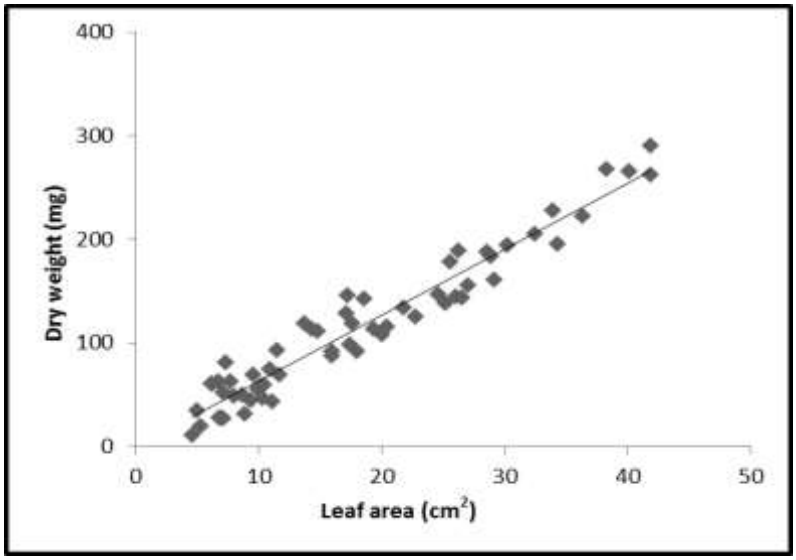

Fig.7 Relationship between Dry weight and leaf area in *Dalbergia latifoia* (N = 60, Y = 6.367x – 0.611, R^2=0.936)

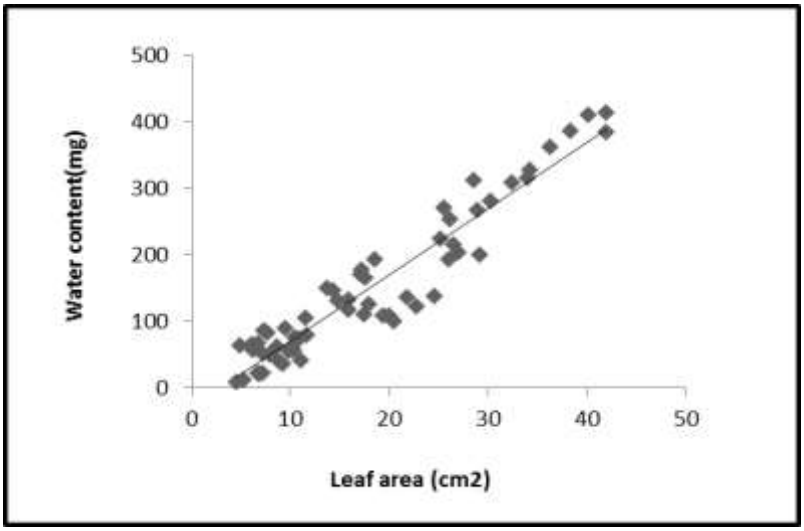

Fig.8 Relationship between water content and leaf area in *Dalbergia latifoia* (N = 60, Y = 10.01x – 30.14, R^2 = 0.909)

Table: 1 Data obtained for leaf area of *D. latifoia* by conventional method and LAM method

No. Of leaves	Leaf area measurement by conventional method(cm^2)	Leaf area measurement by software(cm^2)	Time is consumed in conventional method (minute)
1	3.97	2.86623	2
2	4.49	5.15995	3
3	3.93	3.97762	3
4	3.48	4.51403	2
5	6.28	6.51404	4
6	3.32	2.67705	2
7	5.14	4.86375	3
8	5.65	4.97327	3
9	6.29	5.62417	4
10	7.31	6.73183	5
11	4.92	5.06163	3
12	5.5	6.63227	3

13	8.78	8.18299	4
14	7.24	12.37592	6
15	7.49	11.91917	6

Table: 2 Data obtained for leaf area of *A. nilotica* by LAM software

No.	Fresh weight (mg)	Dry weight (mg)	Water content	Leaf area
1	411.6	198.5	213.1	39.92554
2	44.1	22.4	21.7	13.57568
3	263	148.2	114.8	23.98768
4	370.5	194.2	176.3	63.59835
5	180.7	96.9	83.8	4.76667
6	60	29.7	30.3	35.40529
7	73.4	42.2	31.2	5.47483
8	64.1	31.2	32.9	13.17617
9	35.9	17.5	18.4	3.97513
10	216.4	154.4	62	13.59684
11	82.7	33.1	49.6	5.71378
12	184.7	92.5	92.2	22.64853
13	267	138	129	15.54582
14	212.3	107.2	105.1	23.80598
15	196.5	113.5	83	13.96523
16	93.7	36.3	57.4	5.42007
17	107	41.6	65.4	6.47048
18	104.1	38.1	66	6.20663
19	31.5	19.7	11.8	13.65533
20	78	30.4	47.6	6.81522
21	331.8	175.8	156	27.70519
22	186.9	96.1	90.8	20.41828
23	127	50.8	76.2	8.44435
24	308.7	174.8	133.9	37.39908
25	96.7	52.1	44.6	43.76501
26	419.8	247.8	172	36.11718
27	340.3	199.6	140.7	30.7581
28	207.3	144.6	62.7	22.39838
29	227.7	133.3	94.4	24.35607
30	219.8	130.4	89.4	14.80406
31	137.1	120.7	16.4	11.62172
32	204.5	105.8	98.7	18.10091
33	99.6	53.9	45.7	9.03676
34	196.3	100.1	96.2	14.97083
35	197.2	108.4	88.8	17.52592
36	106.4	59.5	46.9	8.64224
37	114.4	63.3	51.1	9.3367
38	295.4	148.2	147.2	15.40394
39	114.4	48.1	66.3	7.3815
40	187.7	93.6	94.1	13.29565
41	138.1	65.2	72.9	16.21788
42	175.6	95	80.6	11.60678
43	252.5	120.2	132.3	18.86756
44	89.7	42.1	47.6	5.9266
45	129.3	67.2	62.1	9.78972
46	51.8	29.4	22.4	2.83511
47	150.7	82.7	68	14.23032
48	55.3	30.4	24.9	4.89859
49	39.6	23.6	16	5.73867

50	109.3	58.2	51.1	6.37216
51	136	80.6	55.4	8.42444
52	78.6	38.8	49.6	4.37961
53	53.1	27.5	92.2	3.2844
54	94.3	48.2	129	5.59182
55	110.4	56.2	105.1	6.09711
56	103.6	29	83	6.92101
57	131.8	52.3	57.4	5.85068
58	56.8	67.4	65.4	3.47357
59	53	21.8	66	4.24396
60	44.4	14.9	11.8	2.65963

Table: 3 Data obtained for leaf area of *L. leucocephala* by LAM software

No.	Fresh weight(mg)	Dry weight(mg)	Water content	Leaf area
1	60.5	24.4	36.1	27.49642
2	461.9	187.3	274.6	13.41513
3	206.8	85.2	121.6	10.67087
4	274.3	116.2	158.1	15.22348
5	271.1	107.5	163.6	16.03369
6	313.6	132.5	181.1	32.90995
7	93.4	39.1	54.3	6.46799
8	354.7	154.9	199.8	29.46002
9	386.8	164.9	221.9	22.05986
10	634.9	272.3	362.6	37.34058
11	473.3	212.2	261.1	33.53969
12	578	243.2	334.8	36.90997
13	206.3	96	110.3	21.48114
14	690.2	270	420.2	47.77872
15	792	337.3	454.7	54.07247
16	302.6	154.7	147.9	24.93728
17	414.4	181.2	233.2	35.36049
18	1366.1	351.2	1014.9	60.31395
19	959.3	173.1	786.2	75.47271
20	667	227.8	439.2	61.12914
21	586.3	215	371.3	47.70529
22	769.8	294.1	475.7	39.68161
23	407.4	291	116.4	30.89002
24	301.5	132	169.5	23.91674
25	127.3	39.5	87.8	29.85579
26	397.5	190	207.5	26.63238
27	175	59.8	115.2	15.33176
28	496.9	190.6	306.3	18.45187
29	45.8	15.5	30.3	4.62479
30	293.3	108.4	184.9	37.46877
31	289.2	107.7	181.5	25.44009
32	601.3	205.7	395.6	44.45948
33	443.2	151.9	291.3	19.22101
34	212.8	87.3	125.5	32.92612
35	194.2	70.4	123.8	22.18431
36	390.5	162.4	228.1	17.07788
37	184.4	61.5	122.9	30.69338
38	839	286.8	552.2	15.65285
39	497.8	174.6	323.2	48.07991
40	804.5	315.1	489.4	37.36672
41	533.9	214.6	319.3	38.43704

42	375.6	158	217.6	36.30511
43	834.7	349.7	485	60.54046
44	331.3	127.3	204	35.51979
45	465.5	203.5	262	41.79363
46	572.6	231.9	340.7	40.88261
47	406.4	148.9	257.5	31.28704
48	875	396.9	478.1	64.84913
49	196.6	67.9	128.7	18.45187
50	392.6	165.6	227	27.24968
51	713.4	275.6	437.8	54.69724
52	421.1	166.9	254.2	23.6977
53	518.3	177.5	340.8	51.02454
54	770.6	282.7	487.9	38.73698
55	807.3	308.3	499	52.77066
56	310.5	119.5	191	28.25155
57	709	257.9	451.1	64.38367
58	555.8	238.5	317.3	38.21178
59	506.5	197.3	309.2	34.43951
60	642.8	216.6	426.2	42.83781

Table: 4 Data obtained for leaf area of *P. juliflora* by LAM software

No.	Fresh weight(mg)	Dry weight(mg)	Water content	Leaf area (cm^2)
1	435.3	178.01	257.29	27.9317
2	473.4	190.2	283.2	29.83214
3	455.1	176.6	278.5	27.1282
4	517.1	204.2	312.9	32.59009
5	232.1	97	135.1	18.97708
6	585.7	230.5	355.2	38.18066
7	367.5	151.2	216.3	25.53343
8	472.9	199.4	273.5	32.10471
9	309.6	133.3	176.3	23.4799
10	509	216.9	292.1	38.67476
11	420.3	173.6	246.7	30.06488
12	624.2	267.8	356.4	43.69656
13	486	204.1	281.9	33.95413
14	411.9	178.8	233.1	25.77736
15	457.5	195.6	261.9	31.32313
16	426	159.6	266.4	27.30444
17	564.7	202.2	362.5	36.52789
18	582.5	217.1	365.4	42.62002
19	432.3	152.3	280	28.29387
20	445	162.4	282.6	27.18372
21	298	104.5	193.5	20.4021
22	463	174.7	288.3	29.30818
23	390	146.7	243.3	23.98146
24	471.6	173.4	298.2	34.27772
25	398.8	143.5	255.3	20.60372
26	373.3	148.5	224.8	34.0985
27	422.9	156.3	266.6	25.72882
28	429.4	160.6	268.8	43.7787
29	394.3	147.3	247	19.89059
30	441	163.7	277.3	40.14832
31	587.7	246.8	340.9	40.4345
32	530.6	223.1	307.5	32.56645
33	567.2	237.4	329.8	36.48059

34	216	90.4	125.6	13.16746
35	507.3	201.9	305.4	34.58886
36	433.4	183.8	249.6	33.62183
37	367.5	154.5	213	36.22172
38	480.9	219.6	261.3	34.33248
39	376.1	167.2	208.9	43.87453
40	447.5	210	237.5	37.6679
41	521	236.8	284.2	36.25408
42	299.3	146.2	153.1	30.50794
43	308.4	157.5	150.9	26.24532
44	400.1	188	212.1	29.25093
45	295.8	140.1	155.7	29.48616
46	328.5	143	185.5	21.63422
47	322.7	144.3	178.4	18.06606
48	467.3	211.3	256	35.99521
49	429.7	299.6	130.1	30.42331
50	210.5	98	85.9	12.88619
51	383.3	178.3	205	21.2148
52	280.5	124.6	155.9	16.40208
53	391.9	197.8	194.1	25.93667
54	420.5	185.2	235.3	27.79977
55	181.8	86.8	95	16.92355
56	433.6	207	226.6	36.45819
57	446	215	231	41.39039
58	184.5	89.6	94.9	15.33549
59	248.1	112.5	135.6	16.57881
60	409.2	207.2	202	26.35235

Table: 5 Data obtained for leaf area of *D. latifoia* by LAM software

No.	Fresh weight(mg)	Dry weight(mg)	Water content	Leaf area(cm^2)
1	21.1	11.6	9.5	4.57376
2	33.3	20.2	13.1	5.23712
3	50.6	28.1	22.5	6.74926
4	47.9	26.9	21	6.809
5	146.4	62.8	83.6	7.67148
6	71.2	31.7	39.5	8.82021
7	99.9	35.1	64.8	4.93842
8	118.4	60.8	57.6	6.14813
9	127.1	60.5	66.6	6.14067
10	131.4	63.3	68.1	6.65592
11	99.3	48.8	50.5	7.94653
12	49.6	27.4	22.2	7.11267
13	84.9	43	41.9	11.03179
14	103.8	47.1	56.7	10.29501
15	104.5	52.4	52.1	7.11267
16	81.5	44.6	36.9	9.27696
17	167.9	81	86.9	7.24086
18	159.5	69.4	90.1	9.49103
19	148.5	74.5	74	10.86129
20	149.3	69.8	79.5	11.67026
21	113.1	50.1	63	8.59992
22	119.7	58.5	61.2	10.0934
23	136.4	59.8	76.6	10.41449
24	111.1	55.3	55.8	9.86191
25	195.1	92.1	133	15.91794

26	206.1	88.3	117.8	15.91172
27	243.4	111.6	131.8	14.77793
28	260.7	114.1	146.6	14.2913
29	199	93.7	105.3	11.48357
30	269	118.6	150.4	13.68271
31	217	108.3	108.7	19.99637
32	222.6	113.7	108.9	19.36289
33	210.5	98.8	111.7	17.37657
34	300.6	129.3	171.3	17.08783
35	323.4	145.8	177.6	17.20855
36	247.7	125.1	122.6	22.69458
37	270.5	134.1	136.4	21.75618
38	335.7	142.6	193.1	18.50165
39	217	116	101	20.40459
40	364.1	138.7	225.4	25.18122
41	361.3	160.9	200.4	29.13768
42	360	156.1	203.9	26.95223
43	337.9	144.9	193	26.00263
44	476.8	194.8	282	30.24534
45	500.6	188.2	312.4	28.5378
46	676.5	265.6	410.9	40.15703
47	655	267.8	387.2	38.25534
48	703.8	290.1	413.7	41.8907
49	648.6	262.8	385.8	41.89195
50	544.3	227.5	316.8	33.90684
51	586	222.6	363.4	36.30635
52	450.1	178.4	271.7	25.52347
53	524.6	195.6	329	34.26154
54	284.6	118.6	166	17.60557
55	218.3	91.7	126.6	17.92044
56	451.8	183.6	268.2	28.83649
57	442.6	188.8	253.8	26.17687
58	514.4	205.6	308.8	32.40714
59	284.7	146.8	137.9	24.52035
60	359.6	143.7	215.9	26.51165

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