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RAPID ESTIMATION OF LEAF AREAS OF EUCALYPTUS SAPLINGS AND SEEDLINGS

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INTRODUCTION

Determination of leaf area is required for estimation of evapotranspirative demand by *Eucalyptus* spp. replanted on sites mined for bauxite and on dieback (*Phytophthora cinnamomi* Rands.) affected areas in the jarrah (*E. marginata* Sm.)forests of southwestern Australia. Successful management of water demand will depend on the assessment and control of leaf areas over large areas. Values of the leaf area index for natural stands of jarrah forest have been presented by Carbon *et al* (in press). Similar data have been published for *E.signata* F.v.M and *E.umbra* R.T.Bak. (Westman and Rogers 1977). However, no published data are available on any species commonly used for forest rehabilitation in Western Australia.

Measurement of leaf area *per se* is tedious and usually destructive. The method of Carbon *et al*(1979) gives reliable non-destructive estimates and is especially useful for large trees. This method requires trained estimators. Large-scale work may require fast, reliable techniques needing little skill. Techniques are required both for stands of trees and seedlings used in experimental work

In forests various components of yield can be predicted from bole diameter or height, both of which are easily and non-destructively measured in the field (Whittaker and Woodwell 1968). Similarly, harvested seedlings can be weighed very rapidly compared to direct measurement of leaf area. This paper presents leaf area relationships with bole diameter, fresh weight and height for sapling stands of *E.resinifera* Sm., *E.maculata* Hook. and *E.globulus* Labill. Regressions of leaf area on shoot and leaf fresh weight are presented for seedlings of six *Eucalyptus* species.

METHODS

Experiment 1

Sapling trees of *E.resinifera, E.maculata* and *E.globulus* growing in pure stands at 4 x 4m spacing on rehabilitated bauxite mines at Jarrahdale were sampled. These species have been widely planted over a number of years and their use is likely to continue. For stem diameter or height to be useful in predicting leaf area, it was considered that environmental factors should not affect the relationship. Thus variations in fertilisation and ground preparation treatments were ignored. For each species, three trees representing the range of sizes present within each of three stands of different ages, were sampled, Tree heights were measured with a metre rule or Abney level and stem diameters were measured with a diameter tape. Stem diameter was recorded at breast height (1.3m) for all trees over 1.8m high and at ground level for smaller trees. Basal area was calculated from diameter. All leaves with petioles attached were stripped from each tree and total leaf fresh weight immediately determined in the field. Leaves were transported to the laboratory in plastic bags for leaf area determination using a photo-electric planimeter.

Linear regressions were calculated for each growth parameter using data from all trees of each species. Correlation co-efficients (r) were determined for each equation.

Experiment 2

Fourteen month old stock of *E.camaldulensis* Dehnh., *E. globulus*, *E.wandoo* Blakely, *E.marginata*, *E. saligna* Sm. and *E.calophylla* was used to define relationships between leaf area versus shoot weight and leaf weight of seedlings. Depending on the availability of material, three or four plants per species were used. To increase the sample size, seedlings were split into shoots of varying sizes by cutting just above a node at various heights up the stem. Smaller shoots were combined to give larger shoots. In this manner at least eight regression points were obtained per species. Shoot fresh weight was determined immediately after severance. All leaves, without petioles, were promptly removed and their total fresh weight recorded. Leaf areas were then determined with a photo-electric planimeter. Linear regressions of leaf area with shoot fresh weight and leaf fresh weight were calculated for each species and correlation coefficients were determined.

RESULTS

Experiment 1

Age, height, hole diameter, leaf fresh weight and leaf area data for all sampled trees are listed in Table 1. Considerable over-lap in growth parameters is demonstrated, reflecting the sampling criterion referred to above, but also representative of real differences in performance of individual trees on the sites used.

Basal area is plotted with height, leaf fresh weight and leaf area in Figure 1. Values of the regression equation terms for linear regressions of the form

$$y = a + bx$$

for predicting leaf area from bole diameter, basal area, leaf fresh weight and height, are summarised in Table 2. Diameter was a good estimator of leaf area and was more efficient than height for each species. Diameter was the best estimator for *E.maculata* while leaf fresh weight was the best for *E.resinifera* and basal area was the best for *E.globulus*.

Experiment 2

Inspection of shoot and leaf fresh weight versus leaf area data show very good correlation (Table 3). Leaf fresh weight was a slightly better estimator of leaf area than shoot fresh weight for seedlings but significant correlations were obtained using either method.

DISCUSSION AND CONCLUSIONS

Bole diameter was a good estimator of leaf area ($r > 0.920$, $n = 9$, when $p.001 = 0.898$) for *E.maculata, E.resinifera* and *E.globulus* saplings up to 6m height when grown in plantation culture. While basal area is perhaps the most useful measure of growth, especially when heights are variable, and leaf fresh weight versus leaf area yielded marginally better correlation coefficients (Table 2) for *E.resinifera* and *E.globulus,* the use of bole diameter as the field measured variable has advantages. Bole diameter is a simple parameter to measure in the field and can be recorded more readily than the other measures considered. These features strongly recommend its adoption for large scale field surveys.

The range of tree ages used transcended changes in ground preparation and fertilisation techniques developed over the years. Further, the considerable overlap in growth parameters between age groups suggests that the linear regression relationship held independently of growth rates. That is, leaf area and bole diameter increased proportionately faster at higher growth rates. Thus bole diameter could be relied on to give acceptable estimates of leaf area for the species examined, regardless of the environmental history of the trees. Correlation coefficients obtained in this study exceed those found by Carbon *et al* (in press). This is most likely due to the more mature, less uniform trees examined by those workers.

Bole diameter is recommended as an accurate and rapid field estimator of leaf area for sampling *Eucalyptus* spp. trees grown under land rehabilitation conditions. The derived regression equations are listed below. It would be desirable to confirm these equations when a wider range of age classes becomes available.

E.maculata $y = -3.81 + 5.23x$

E.resinifera $y = -22.3 + 9.28x$

E.globulus $y = -25.3 + 9.04x$

where y = leaf area in $cm^2 \times 10^3$ and x = bole diameter in cm.

For seedlings, the use of multiple shoots from one plant did not appear to materially alter the regression obtained when only one shoot per plant was used. As the use of multiple shoots increased the range of points, the multiple shoot equations reported here are recommended for future use in estimating leaf areas of the six species tested.

Although leaf weight was a slightly better estimator of leaf area than shoot weight for seedlings, the high correlation coefficients recorded for shoot weights ($r > 0.950$, $n = 8$, when $p.001 = .925$) renders this method most attractive in view of the considerable time saved by not removing the leaves. Appropriate regression equations are:

E.camaldulensis	$y = 329 + 11.3x$	
E.globulus	$y = 201 + 14.1x$	
E.wandoo	$y = 49 + 13.3x$	
E.marginata	$y = 345 + 10.8x$	
E.saligna	$y = 90.9 + 17.5x$	
E.calophylla	$y = 5.51 + 18.0x$	

where y = leaf area in cm^2 and x = shoot fresh weight in g.

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TABLE 1. Growth data for sapling Eucalyptus trees growing on rehabilitated bauxite mines (*for stems < 1.8m tall, basal stem diameter; > 1.8m, diameter at 1.3m).

Species	Age (yr)	Height (m)	Bole Diameter (cm) *	Leaf Fresh Weight (kg)	Leaf Area ($cm^2 x 10^3$)
E.maculata	1	2.15	7.5	1.3	39.31
		1.25	2.3	0.35	8.77
		0.72	2.0	0.25	6.96
	7	5.25	13.2	6.5	65.83
		4.1	11.2	5.4	55.50
		2.1	7.1	1.28	33.70
	9	5.78	13.7	7.1	70.10
		4.5	12.0	5.9	58.30
		3.2	9.1	1.5	35.50
E.resinifera	2	4.25	17.5	7.1	168.00
		1.63	5.0	0.7	27.63
		0.75	2.75	0.3	7.20
	4	3.7	9.8	3.5	65.55
		2.7	7.2	1.8	53.24
		0.95	3.2	0.45	8.13
	8	6.2	18.3	6.8	145.30
		4.2	15.2	3.6	98.05
		2.3	10.4	1.75	55.39
E.globulus	3	3.1	8.2	2.9	32.35
		1.89	3.8	0.9	15.78
		1.2	2.7	0.75	13.35
	6	5.05	12.5	5.25	88.56
		4.8	9.7	3.8	58.65
		3.7	7.5	3.2	49.64
	8	6.2	15.5	7.2	140.25
		5.4	12.5	5.2	78.98
		4.8	9.5	3.8	35.78

TABLE 2. Leaf area versus growth parameters, regression constants (a) coefficients (b) and correlation coefficients (r) for sapling Eucalyptus trees.

	E.maculata				*E.resinifera*				*E.globulus*			
	Bole Diameter	Basal area	Leaf fresh weight	Height	Bole Diameter	Basal area	Leaf fresh weight	Height	Bole Diameter	Basal area	Leaf fresh weight	Height
a	-3.81	11.47	16.7	1.43	-22.3	13.50	7.28	-15.9	-25.3	5.63	-11.2	-26.4
b	5.23	0.42	7.56	12.4	9.28	0.55	21.70	28.9	9.04	0.67	18.60	20.8
r†	0.989	0.975	0.935	0.965	0.967	0.970	0.982	0.902	0.924	0.971	0.951	0.858

† All r values significant at 1% level

TABLE 3. Leaf area versus shoot weight and leaf weight regression constants *(a)*, coefficients *(b)* & correlation coefficients *(r)* for Eucalyptus seedlings.

n = number of samples

Shoot Fresh Weight	*E. camaldulensis*	*E. globulus*	*E. wandoo*	*E. marginata*	*E. saligna*	*E. calophylla*
n	8	8	9	8	10	9
a	329	201	49.0	345	90.9	5.51
b	11.3	14.1	13.3	10.8	17.5	18.0
r+	0.959	0.965	0.996	0.988	0.991	0.978
Leaf Fresh Weight						
n	8	8	9	8	10	9
a	16.0	-104	-0.160	254	30.7	-32.7
b	28.9	30.6	20.4	20.2	36.0	27.4
r+	0.995	0.980	0.999	0.993	0.993	0.995

+ All *r* values significant at 0.1% level.

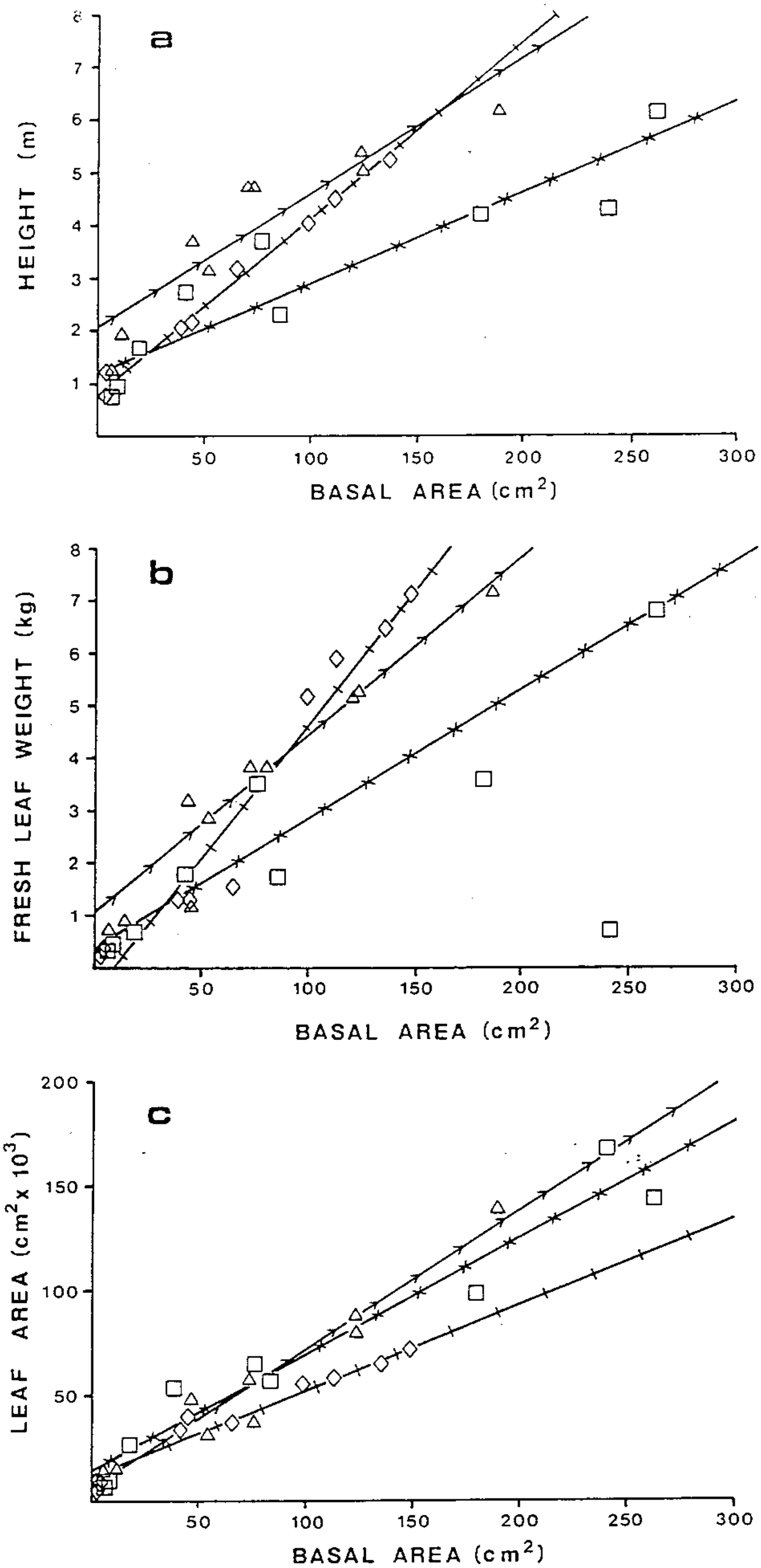

FIG. 1 Relationships between basal area and (a) height, (b) leaf weight, (c) leaf area, showing individual values and regression lines for three species (◇ —+—+— *E.maculata*, □ —×—×— *E.resinifera*, △ —→—→— *E.globulus*).