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APPLICATION OF THE DIAGNOSTIC AND REMMENDATION INTEGRATED SYSTEM (DRIS) TO YOUNG PLANTATION EUCALYPTS IN NEW ZEALAND - A PRELIMINARY EVALUATION BASED ON PROVISIONAL STANDARDS

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EXECUTIVE SUMMARY

Provisional Diagnosis and Recommendation Integrated System (DRIS) standards were developed for three species of eucalypt (*E. regnans*, *E. Saligna* and *E. delegatensis*).

The standards for each species were calculated from a very narrow, but survey-based database relating to 2- and 3-year-old eucalypts (sampled nationwide in summer 1988). The standards were found to be sufficiently different between species to preclude combining data for the three species. A single test was applied to each of the *E. regnans* and *E. saligna* standards using independent data from a nutrient subtractive trial (AK 1023-2) located in Tairua SF. As no suitable test data currently exist for *E. delegatensis*, standards for this species could not be tested.

Considering the narrowness of the databases, the results of very limited testing of the provisional standards for *E. regnans* and *E. saligna* are reasonably encouraging; they allow room for cautious optimism, that DRIS can be usefully applied to these species for diagnostic purposes. However to improve the reliability and accuracy of DRIS for young NZ eucalypts, the database needs to be expanded. Also, for species of interest, factorial fertiliser trials need to be established at nutrient-poor sites to provide suitable response and foliar data for more thorough testing of provisional DRIS standards.

INTRODUCTION

THE DRIS SYSTEM

The diagnostic and recommendation integrated system (DRIS) recognises antagonisms and synergisms among plant nutrients and emphasises the importance of balance among nutrients rather than individual nutrient sufficiencies. In essence, DRIS is a mathematical means of ordering a large number of nutrient expressions (such as ratios or products of various nutrient pairs) into simple nutrient indices that can be more easily interpreted.

The system was developed by Beaufils (1957, 1971, 1973) over a 20 year period. Beginning with rubber, he went on to develop and refine the system for maize in South Africa, and later applied it to other crops such as potatoes, ryegrass, lemons and soya beans. In later work, Beaufils collaborated with Sumner to apply the DRIS approach to sugar cane (Beaufils and Sumner 1976, 1977). Since that time, Sumner (1977a, b, c, 1978) and various other researchers (Elwali and Gascho 1984; Davee *et al* 1986; Alkoshab 1986; Mackay *et al* 1987, Righetti *et al* 1988a, 1988b) have extended the application of DRIS to other arable, horticultural, or orchard crops.

Fundamental to the development of DRIS was the observation (Beaufils, 1973) that the higher the yield the smaller the variation of analytical values around their means; in other words the coefficient of variation is lower at high yield levels.

Successful application of the concept to a species requires (1) foliage analysis data from a large number of sites (2) matching crop productivity values for each foliage sample, and (3) independent foliar and growth (productivity) data for that species, e.g. from factorial fertiliser trials. (1) and (2) are needed for determination of important nutrient expressions for DRIS index equations and/or the calculation of DRIS standards, and (3) for testing the validity and accuracy of the DRIS standards. One procedure commonly used in DRIS is to divide the sample population into 'desirable' and 'undesirable' populations (on the basis of productivity) so that norms for the 'desirable' or high yielding population can be calculated.

The advances in computing facilities which have occurred in the last decade now make contemporaneous and statistical treatment of large amounts of diverse data a relatively simple matter, so that, with suitable programming, the numerous and varied computations which DRIS involves can now be carried out efficiently and quickly.

In a critical review of DRIS, Jones (1981) summarised the basic assumptions which underly the system as follows:

(1) Ratios of nutrient element concentrations are often better indicators of nutrient deficiencies than single nutrient element concentrations.

(2) Concentration ratios for some nutrient elements are more important than others.

(3) Maximum crop yields are attainable only when the values of 'important' ratios approach an optimum value; for a particular ratio, the mean value for a selected high-yielding (or otherwise desirable) population approximates the optimum value.

(4) Since 'important' ratios must approach their optimum values for high yields to be attained, the variance of an 'important' ratio is smaller in a high yielding population than a low-yielding one. Thus the ratio of the variance in a low-yielding population to that in a high-yielding one can be used to select important ratios.

(5) A DRIS index can be calculated for each nutrient element determined. This index is based on the mean deviation of each important ratio (in which the nutrient element is either the numerator or denominator) from its optimum value. The optimum DRIS index for any nutrient element is zero, with a negative index indicating relative deficiency, and a positive one indicating relative sufficiency.

In recent years there has been increasing interest by forest nutritionalists in DRIS application to forest crops (See reviews by Mead (1984), Powers (1984), Weetman and Wells (1986), and Schutz and de Villiers (1987)).

Leech and Kim (1979) used DRIS to assess the nutrient requirements of poplars, and subsequently (Leech and Kim, 1981 and Kim and Leach, 1986) as a guide to fertiliser strategy for poplar plantations.

Truman and Lambert (1980) used the same technique to study the balance between foliar N, P and S in *Pinus radiata* growing in NSW.

Svenson and Kimberley (1988) using site index data, examined the diagnostic potential of DRIS norms for *Pinus radiata* growing under New Zealand conditions. Their study was limited to a range of macronutrients (N, P, K, Ca, and Mg).

In Western Australia, Ward *et al.* (1985) calculated separate DRIS indices for N, P, K, Ca and Mg for six types of *E. saligna* tissue (newly expanding foliage, young fully expanded foliage, older leaves, twigs, branches, and fruit) in upper and lower canopy positions. They found that only DRIS indices for fully expanded leaves of the upper crown successfully predicted and ranked the nutrient deficiencies previously established from responses to nutrients in a factorial fertiliser trial.

In Hawaii, Yost *et al.* (1987) used DRIS to study the effects of N and P fertilisation on the early growth and nutrient status of *E. saligna*. They reported that, in general, DRIS indices for N and P were more strongly related to present size or growth increments for the initial 12, 18 or 24 months from planting, than were absolute concentrations of these elements.

The present study is a first attempt at establishing and testing DRIS standards for New Zealand populations of young (2 and 3-year-old) plantation eucalypts (*E. delegatensis, E. regnans* and *E. saligna)*. The standards for each of these study species were based on data from a recent NZ-wide survey of nutrient concentrations in eucalypts conducted in summer 1988.

METHODS

In this study, in adopting the proposition (Jones 1981) that both the mean and/or variance of 'desirable' and 'undesirable' populations be used as criteria for selecting nutrient ratios for DRIS formulae, we have included all possible 'important' ratios.

Two of three modifications to standard DRIS computation originally proposed by Beverly (1987) were also adopted in the present study namely:

1. Use of logarithmic transformation of nutrient ratio data to reduce skewness in the distribution of concentration ratio values, and to simplify computations (see below)

2. Use of a single index calculation method; this replaces the practice of using two alternative equations (to calculate the function describing variation of the observed nutrient ratio

from the diagnostic value) and choosing one according to whether the observed value is greater than or less than the diagnostic norm. Logarithmic transformation eliminates any need to choose between alternative forms of expression as, by simplication, it renders them equivalent:

$$(1)\quad f(A/B) = \frac{(\ln(A/B)/\ln(a/b)) - 1}{CV} \quad <=> \quad \frac{(\ln(A/B) - \ln(a/b)) / \ln(a/b)}{SD / \ln(a/b)}$$

$$(2)\quad <=> \quad \frac{\ln(A/B) - \ln(a/b)}{SD}$$

where

A/B = the value of the ratio of two elements, A and B in the tissue of plants being diagnosed

a/b = the optimum value or norm for that ratio

SD = the standard deviation of the norm

CV = the coefficient of variation of the norm.

It will be noted that, in the above simplification, standard deviation replaces coefficient of variation. The third modification which Beverly suggested, i.e. using population parameters rather than high-yield subpopulation values, was not adopted as it was felt that the very limited database available would make such a procedure unwise.

DATABASE

The datasets (see Appendix Tables 1.1-1.3 incl.) used in this study to establish provisional DRIS standards for three eucalypt species (*E. regnans*, *E. saligna* and *E. delegatensis*) were taken from a recently-established FRI databank for eucalypts. These datasets are referred to hereafter as the 'standards' datasets. The databank, consisting of foliar concentration and tree height data, was created from the results of countrywide NZ survey of 2 and 3 year-old stands of various eucalypt species conducted in summer, 1988. The datasets for eucalypt species other than *E. delegatensis*, *E. regnans* and *E. saligna* were too limited to warrant inclusion in this DRIS study.

TABLE 1 - Synopsis of survey sample numbers by region (South or North Island). and stand age for the three species used in the DRIS study. Figures in square brackets indicate the number of different sites

Species	2-year-old stands			3-year-old stands			Both ages+ grand total
	SI	NI	Sum	SI	NI	Sum	
E. delegatensis	15[9]	0[0]	15 [9]	24[13]	3[2]	27[15]	42[23]
E. regnans	18[8]	8[5]	26[13]	16 [9]	10[5]	26[14]	52[26]
E. saligna	3[1]	17[9]	20[10]	0 [0]	14[7]	14 [7]	34[16]

+ Sites common to both age classes are counted only once in the grand total.

The datasets used in this study are minimal for the purpose of DRIS development and the results of the study must therefore be treated with some caution. It is urged that, as resources allow, the database be suitably expanded so that the provisional DRIS standards can be revised on the basis of a larger sample population.

MEASUREMENTS

Statistical analysis and computations

All statistical analyses and computations for DRIS were conducted using Genstat (Lawes Agricultural Trust 1990).

Foliage samples and chemical analyses

Foliage samples collected during the 1988 (summer) survey were taken from the upper third of sunlit crown. Each sample was a composite from at least 12 trees of comparable size. At variables sites trees were stratified by size and separate samples were collected from each size category. The leaves sampled were those which had developed during the current season and which were fully expanded or very nearly so. In the field, i.e. while the foliage samples were still fresh, all petioles (leaf stalks) were detached from the base of the leaf blade and were discarded. The aim of this was to make the samples more consistent. A separate study examining the effect of detaching the petioles on nutrient levels in the eucalypt foliage samples is described in Appendix 10.

The South Island samples were collected between 29 February and 17 March 1988 and the North Island samples between 14 March and 7 April 1988. As far as practicable, samples consisted of undamaged leaves. However it was occasionally necessary to take foliage which was damaged by either wind[1] , insects or fungal pathogen. After drying to constant weight at 70°C on aluminium trays the samples were finely ground in a stainless steel Wiley mill and stored in plastic containers. They were subsequently analysed for 14 elements: N, P, K, Ca, Mg, S, Al, Na, B, Cu, Cl, Fe, Mn and Zn. Nitrogen was determined colorimetrically by the indophenol blue method after a micro-Kjeldahl digestion of a subsample. Copper and boron were determined in solutions prepared by dry ashing subsamples at 480°C and then dissolving the ash in 2N HCl. Boron was determined colorimetrically by the curcumin/acetone method and copper by atomic absorption spectrophotometry. All other elements were determined by X-ray fluorescence spectrometry.

Sample tree size

Each tree sampled for foliage was measured by height pole at time of sampling. Individual tree heights, at least 12 per sample, were later averaged to provide a mean.

Productivity index for DRIS

One of the basic assumptions which DRIS makes is that a 'high yield' population is under less nutritional stress than a 'low yield' population. Accordingly one method of calculating DRIS norms calls for the total dataset to be divided into two subsets on the basis of an appropriate productivity index.

In this study there were insufficient sample numbers to allow DRIS norms to be calculated separately for each age category of a species sampled. It was decided therefore to combine the datasets for the different age categories and to use an approximation to mean annual height increment ('MAI') for each sample as the productivity index. As no information was available on initial (outplanting) height, and as initial height would not be expected to unduly weight the results for one age category more than the other, it was felt that it could be disregarded. Accordingly an approximation to MAI ('MAI') was calculated as:

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[1] As the North Island was surveyed within a week or two of the passage of Hurricane 'Bola', collection of undamaged leaves was not possible at exposed sites.

'MAI' = mean height (m)/stand age (years)

For each species studied the general mean of 'MAI' for the total dataset (i.e. for both stand age categories), was used to separate the sample population into desirable 'or high yield' and undesirable or 'low yield' subsets. The general mean values (m) were variously 1.45, 1.85 and 2.25 for *E. delegatensis*, *E. regnans* and *E. saligna*.

Transformation of data

For each species, distributions of the values of the ratios of individual nutrient pairs in the population sample were tested for normality; those for several nutrient ratios were found to be significantly skewed. Natural logarithmic transformation of the data (a prerequisite to using the simplified form of function advocated by Beverly (1987) for DRIS index calculations) successfully corrected skewness (restored normality). This was important to ensure that statistical (F and t) tests could be validly applied to data for selecting 'important' ratios (see next section).

Selection of nutrient ratios for DRIS formulae

DRIS assumes that there is an optimal ratio between any two elements in plant tissue and that a departure from the optimum is associated with poorer growth. Thus the initial step in the form of DRIS computation used in this study was to divide the dataset for each species into 'high yield' (H) and 'low yield' (L) subsets using 'MAI' (see above) as an index of productivity. Once this was done, the subset means and variances for individual ratios were calculated for each nutrient pair. The numerator in each ratio of nutrient pairs was arbitrarily taken as the first of the pair to appear in the sequence: N P K Ca Mg S B Cu Fe Mn Zn Al Na Cl.

In view of the narrowness of the database, it was considered that the testing of alternative nutrient expressions, such as inverse ratios or products of nutrient pairs, was not warranted in this preliminary study. Such testing would be done in a similar way to selecting 'important' ratios i.e. by picking the nutrient expression (A/B, B/A or A*B) with the largest variance ratio (S^2_L/S^2_H). Substituting the selected form of expression in the DRIS equations should, to some extent, enhance diagnostic accuracy and would be the logical next step in refining the DRIS after expansion of the database.

For the purposes of DRIS, the 'high yield' or desirable population is assumed to be under less nutritional stress than the 'low yield' or undesirable population. Thus, if a component of the undesirable population is stressed for a particular nutrient, the variance about the mean for the nutrient ratio involving that nutrient should have greater variance than that for the same ratio for the desirable population (Beaufils, 1973). Also, if it is assumed that the optimum value of a particular nutrient pair ratio approximates the mean value ($\bar{X}_H$) of the ratio in the desirable population, then for a particular nutrient ratio to be important, $\bar{X}_H$ should be greater than $\bar{X}_L$.

Accordingly the variances (S^2) and means ($\bar{X}$) for ratios of all possible element pairs from the 14 elements determined were calculated for the two subsets of data. The variance ratios (S^2_L/S^2_H) were subjected to the F test, and the paired means ($\bar{X}_H$ and $\bar{X}_L$) to t test. Selection of important nutrient ratios for the DRIS computation was based on one or both of the following criteria:

(1) significantly different variances: $S^2_L > S^2_H$ ($p \leq 0.05$); provided $\bar{X}_H > \bar{X}_L$†
(2) significantly different means: $\bar{X}_H > \bar{X}_L$ ($p \leq 0.05$)

Formulation of DRIS index equations

The DRIS index equations for individual nutrients were formulated in the standard way, i.e. by (1) assembling all the nutrient ratios evaluated as important for that nutrient, and (2) writing them as functions, e.g. f(A/B), assigning a positive or negative value to each function depending whether the nutrient being indexed appears as the numerator (positive) or denominator (negative) in the ratio, and (4) dividing the resultant sum of functions by the total number of functions in the numerator. Thus, for example, assuming element A features in four 'important' ratios (A/B, A/C, A/D and E/A) the equation would be written as follows:

$$\text{DRIS A-index} = \frac{f(A/B) + f(A/C) + f(A/D) - f(E/A)}{4}$$

The simplified formula (Beverly, 1987) used to derive a function of two elements for DRIS was as follows:

† regardless of whether or not the difference between $\bar{X}_H$ and $\bar{X}_L$ attained significance at the 5% level

$$f(A/B) = \frac{\ln (A/B) - \ln (a/b)}{SD}$$

where: $f(^A/_B)$ = a function of two elements for DRIS

$^A/_B$ = ratio of the concentration of two elements A and B in a foliage sample

$^a/_b$ = the optimum value or norm for that ratio

SD = standard deviation of the log-transformed norm

ln = natural log.

Individual index formulae for the three datasets (i.e. for *E. regnans*, *E. saligna* and *E. delegatensis)* are listed in Appendix Tables 3.1-3.3 incl. Shortened formulae used to calculate DRIS indices for test data (for which the range of nutrients determined was smaller) are given in Appendix Tables 7.1-7.3 incl.

Interpretation of DRIS data

In a validated DRIS system, a positive index indicates a relative excess or surplus, whereas a negative index indicates a relative deficiency. The index with the largest negative number should indicate the element in the shortest supply, while the larger the sum of the absolute values of the indices, the more serious the overall nutritional importance. Thus, the absolute sum of DRIS indices for a sample affords some measure of the total nutritional balance; a low value indicates sound nutritional balance, but does not preclude other factors which may be adversely affecting growth; a high value indicates that poor growth is associated with seriously unbalanced nutrition.

RESULTS AND DISCUSSION

DRIS standards and nutrient ratios

The nutrient ratios, selected on a statistical basis (see Methods) as important for the purposes of DRIS, are listed in Appendix Tables 2.1-2.3 incl. for each of the eucalypt species studied, together with the corresponding DRIS standards (log-transformed means and standard deviations for the 'high yield' subgroup) and variance ratios (i.e. for the high and low yield subgroups).

Although the standards for particular nutrient ratios for the two more closely related ('ash group') eucalypts (*E. regnans* and *E. delegatensis)* may appear, after log transformation, rather similar the differences are in fact quite large in untransformed terms. Thus, there did not appear to any acceptable grounds for combining the two datasets to obtain a single set of DRIS standards for the two species. Foliar data for *E. saligna* and *E. regnans* drawn from fertiliser trial AK 1023-2 and used to test the DRIS standards, indicate that these two species, growing on the same soil under the same conditions, can have very different concentrations in their foliage of certain nutrients, namely Ca, Mg, B, Cu, Mn and Zn. Tentatively, it seems therefore that separate standards will be required all three species.

The formulae used to calculate DRIS indices for the full datasets are listed for each species in Appendix Tables 3.1-3.3 incl. Listings of DRIS indices for the complete dataset of each species are given in Appendix Tables 4.1-4.3 incl.

Relationship between 'MAI' and absolute sum of DRIS indices

Some measure of the total nutritional balance in a plant may be indicated by the absolute (i.e. with signs disregarded) sum of DRIS indices (Walworth and Sumner 1987). Thus for DRIS to be diagnostically effective there should be a distinctive inverse relationship between yield or productivity index (in this study 'MAI') and absolute sum of DRIS indices. Encouragingly, the scatterplot diagrams of 'MAI' on sum of DRIS indices using the full datasets for each of species (Appendix 5 : Figures 1-3) show a clear trend for 'MAI' to decrease with increasing absolute sum of indices.

Testing the provisional DRIS norms

The provisional DRIS standards calculated from the *E. regnans* and *E. saligna* datasets derived from the 1988 survey of eucalypt foliar levels, were subjected to a preliminary test to examine their validity. No suitable, independently gathered data was available to test the *E. delegatensis* standards.

The growth and foliar data (Appendix 6) used as a test application of the standards for *E. regnans* and *E. saligna* respectively came from a nutrient subtractive trial (AK 1023-2) recently conducted with these two species in Cpt 111, Tairua Forest. The soil at this site is a moderately acid (pH 5.8), strongly leached and podzolised, composite yellow-brown pumice soil on yellow brown loam. The soil type is Whangamata gravelly sand and the parent material Whangamata ash on Waihi ash on Hamilton ash. The surface soil is very low in available phosphorus (P)

Limitations of the present study

1. Narrowness of database

The survey which provided the database for this study had to be conducted within tight budgetary limits. In order to stay within these limits as well as to keep within a brief sampling period (to avoid seasonal effects), many potential sites for sampling 2 or 3-year-old eucalypts had to be omitted.

It follows that the datasets for individual eucalypt species and separate age categories (Appendix 1) are not as large as could be wished. As large sample populations are considered necessary for accurate, valid diagnostic standards, the standards which we have calculated should be considered as strictly provisional.

2. Lack of suitable test data

It was not possible in this study to test the provisional *E. delegatensis* norms as suitable independently derived data were not available. For the other two species, the limited test data which are available are for a narrower range of nutrients than exist in the dataset. Consequently DRIS indices based on a smaller range of nutrient ratios had to be computed. Also, unlike the survey data used to calculate standards, the foliar data for the test sets relate to foliage samples in which leaf stalks were included with leaf blades. The extent to which inclusion of leaf stalks influences concentration was the subject of an associated study (see Appendix 10).

3. Applicability

The conditions to which the system is ultimately applied should be confined to those to which are represented in the database viz. stands aged 2-3 years sampled in late summer (early March) with foliage samples consisting of leaves which had developed during the current season and which were either fully expanded, or very nearly so.

Suggestions for future work

1. Expansion of database

For DRIS standards to properly represent a population a large database is essential. At present the full datasets for *E. regnans*, *E. saligna* and *E. delegatensis* are based on only 52, 34 and 42 samples respectively. It is suggested that the datasets for *E. regnans* and *E. delegatensis* at least be doubled and that for *E. saligna* be trebled.

2. Independent data for testing provisional norms

A vital step in the successful development of DRIS for any crop is the testing of standards to assess their reliability and accuracy for diagnostic and recommendation purposes. Suitable independently gathered data are needed for this testing. Factorial fertiliser experiments which have shown large responses to specific nutrients can provide such data.

At present, data suitable for testing standards for *E. regnans* and *E. saligna* are rather limited, and for *E. delegatensis* are non-existent. There is therefore a need to establish a suitable factorial fertiliser trial with *E. delegatensis* on a responsive site to provide suitable test data. More comprehensive factorial fertiliser trials for the other two species are also desirable for more comprehensive testing of standards.

3. Use of products or inverted ratios for selected nutrients in DRIS formulae

Walworth and Sumner (1987) have suggested that, to counteract leaf age effects on DRIS indices, the use of products of nutrient pairs rather than ratios may be more appropriate in some instances in the calculation of indices. Thus for example, when a nutrient such as Ca, which tends to increase in foliar concentration with maturity, is related to nutrients such as N, P and K, which may show the opposite trend, products from the two groups (e.g. N x Ca instead of N/Ca) are likely to be the most constant form of expression. This could be a profitable avenue to explore once a larger database has been created. At the same time the testing of inverted ratios (e.g. P/N instead of N/P) is also desirable to maximise the diagnostic accuracy of DRIS index equations where possible.

4. Productivity index : need for review

Using the general mean 'MAI' for the dataset as the cut off value to divide the 'high' and 'low' yield populations may tend to weight the number of samples from 3-year-old stands which fall in the 'high' yield subset relative to that of samples from 2-year-old stands. This is because current annual increment for eucalypts is usually greater in the second and third year than in the first. Data for *E. regnans* from a trial testing the interaction of intensity of weed control with fertiliser treatment on a range of special purpose species (RO 2015-2) helps to illustrate this:

Treatment	'MAI' for initial 2 years	'MAI' for initial 3 years	Difference (%)
$H_1 F_1$	2.43	2.59	9.4
$H_1 F_0$	2.34	2.54	9.2
$H_0 F_1$	1.91	2.10	9.1
$H_0 F_0$	1.52	1.99	7.6

Key + treatments

H_1 = max. weed control
H_0 = min. weed control
F_1 = fertilised at planting
F_0 = no fertiliser

However, the actual cut-off value used is not critical provided the 'high yield' data remains normally distributed (Walworth and Sumner 1985). Although the weighting incurred by using 'MAI' may be unimportant in its effect on DRIS, this aspect of the study merits closer scrutiny. Choice of productivity index may need reviewing in any revision of the provisional DRIS standards.

5. A watch on world literature on DRIS

DRIS methodology continues to be modified and improved. A recent modification (Hallmark *et al.* 1987) separates situations where nutrients do, or do not limit yield, and employs nutrient concentrations as well as nutrient ratios in DRIS equations. This modified system (M-DRIS) was reportedly much better than DRIS is identifying non-limiting situations for soybeans (Hallmark 1988), but has not been evaluated for forestry. Such a development illustrates the importance of keeping abreast of developments in DRIS methodology through a watch on world literature on this topic.

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NOTES

1. The hatched line in each table separates samples of the two stand age-classes

2. The two subject categories shown are 'high' (H) and low (L) 'MAI' respectively. The distinction is made on the basis of the mean value of 'MAI" for each species dataset.

APPENDIX TABLE 1.1 E. regnans : dataset used for computing DRIS norms

	Log. no.	Forest name	Sp.	Surv. ref.	Stand age (yrs)	Av. ht (m)	N	P	K	Ca	Mg	S	B	Cu	Fe	Mn	Zn	Al	Na	Cl
							------ percent ovendry weight -----						------ ppm ------					---- percent ---		
1	F16154	ORET	EUREG	2	2	7.5	2.438	0.171	0.792	0.363	0.217	0.154	17	5.4	78	97	19	0.005	0.108	0.554
2	F15957	LONG	EUREG	3	2	4.8	1.724	0.127	0.567	0.350	0.216	0.123	15	3.2	67	637	16	0.004	0.105	0.387
3	F15992	HERB	EUREG	12	2	5.3	1.801	0.068	0.694	0.337	0.218	0.143	18	2.0	84	539	18	0.011	0.247	0.641
4	F15993	HERB	EUREG	12	2	3.6	1.165	0.071	0.560	0.403	0.285	0.137	19	3.1	64	610	17	0.009	0.201	0.583
5	F15994	HERB	EUREG	12	2	1.2	0.807	0.087	0.451	0.423	0.324	0.127	17	1.4	54	1123	12	0.014	0.212	0.699
6	F16158	CHAR	EUREG	15	2	5.2	1.794	0.110	0.433	0.378	0.288	0.121	11	2.5	69	599	16	0.013	0.179	0.709
7	F16011	GDNS	EUREG	21	2	6.5	2.031	0.211	0.703	0.319	0.197	0.138	20	2.5	66	357	18	0.004	0.042	0.099
8	F16012	GDNS	EUREG	21	2	3.6	1.103	0.135	0.583	0.340	0.224	0.097	18	1.9	44	468	14	0.008	0.044	0.287
9	F16013	GDNS	EUREG	21	2	1.5	0.977	0.195	0.532	0.535	0.350	0.081	20	1.8	74	955	13	0.010	0.045	0.407
10	F16017	GDNS	EUREG	23	2	6.6	1.730	0.130	0.644	0.340	0.172	0.118	22	2.2	84	1407	14	0.005	0.053	0.273
11	F16019	GDNS	EUREG	23	2	3.9	1.065	0.108	0.513	0.513	0.204	0.086	23	1.4	42	2533	12	0.006	0.050	0.431
12	F16020	GDNS	EUREG	23	2	2.5	0.871	0.085	0.517	0.393	0.225	0.073	15	1.2	59	1606	12	0.006	0.057	0.497
13	F16021	GDNS	EUREG	23	2	1.4	0.721	0.152	0.491	0.525	0.342	0.081	18	0.8	65	2796	12	0.008	0.062	0.558
14	F16026	WAWG	EUREG	25	2	7.0	1.867	0.187	0.740	0.328	0.189	0.135	16	4.0	79	106	17	0.005	0.072	0.237
15	F16027	WAWG	EUREG	25	2	3.4	1.763	0.160	0.635	0.410	0.225	0.101	17	4.3	45	302	18	0.004	0.076	0.305
16	F16028	WAWG	EUREG	25	2	1.9	1.131	0.183	0.540	0.541	0.283	0.070	21	2.5	68	420	15	0.007	0.075	0.380
17	F16044	MEKA	EUREG	32	2	4.5	1.147	0.065	0.583	0.401	0.269	0.088	20	2.5	43	943	14	0.007	0.092	0.473
18	F16045	MEKA	EUREG	32	2	2.0	1.535	0.098	0.652	0.419	0.338	0.110	16	3.6	59	1242	15	0.007	0.077	0.370
19	F16057	TGIO	EUREG	35	2	4.1	2.042	0.177	0.825	0.555	0.160	0.142	17	4.1	61	431	18	0.007	0.179	0.456
20	F16058	TGIO	EUREG	35	2	1.5	1.246	0.151	0.562	0.612	0.212	0.095	16	3.6	60	429	16	0.008	0.161	0.401
21	F16063	NAPR	EUREG	37	2	4.0	2.426	0.150	0.574	0.419	0.274	0.161	20	5.8	100	770	22	0.006	0.183	0.614
22	F16116	KAWR	EUREG	51	2	8.7	1.776	0.174	0.734	0.573	0.213	0.128	18	3.9	91	141	17	0.012	0.122	0.564
23	F16120	TIRU	EUREG	53	2	5.6	1.924	0.109	0.420	0.559	0.385	0.128	21	3.9	57	601	16	0.011	0.205	0.817
24	F16121	TIRU	EUREG	53	2	2.7	1.541	0.074	0.359	0.656	0.382	0.131	21	4.1	48	1171	18	0.008	0.139	0.593
25	F16128	TANE	EUREG	56	2	7.8	2.408	0.151	0.924	0.504	0.210	0.172	33	7.2	74	164	22	0.008	0.111	0.421
26	F16129	TANE	EUREG	56	2	3.3	2.226	0.144	0.772	0.911	0.271	0.160	36	8.8	83	230	22	0.010	0.113	0.477
27	F15958	LONG	EUREG	3	3	1.7	1.276	0.126	0.525	0.344	0.227	0.106	15	1.9	57	760	13	0.016	0.136	0.389
28	F15959	LONG	EUREG	4	3	6.1	1.438	0.108	0.712	0.406	0.248	0.113	17	2.6	50	847	15	0.005	0.121	0.537
29	F15961	LONG	EUREG	4	3	2.3	1.317	0.104	0.600	0.372	0.251	0.101	21	2.5	56	536	14	0.007	0.253	0.657
30	F15969	MACL	EUREG	5	3	7.5	1.412	0.110	0.587	0.319	0.247	0.116	17	2.6	72	535	15	0.008	0.197	0.606
31	F15970	MACL	EUREG	5	3	1.7	0.813	0.100	0.435	0.311	0.285	0.075	16	1.2	29	813	10	0.007	0.166	0.457
32	F16162	BALM	EUREG	16	3	2.0	0.948	0.129	0.641	0.273	0.254	0.084	14	2.5	51	306	14	0.008	0.062	0.509
33	F16003	GDNS	EUREG	19	3	5.3	1.518	0.123	0.569	0.387	0.195	0.133	14	0.7	42	147	15	0.005	0.080	0.235
34	F16004	GDNS	EUREG	19	3	1.6	0.857	0.155	0.608	0.459	0.246	0.071	23	1.7	40	216	13	0.004	0.041	0.247
35	F16023	GDNS	EUREG	24	3	1.8	0.896	0.111	0.530	0.351	0.236	0.071	16	1.3	35	718	12	0.004	0.048	0.297
36	F16032	WIRU	EUREG	26	3	7.0	1.248	0.162	0.917	0.262	0.179	0.153	14	2.8	78	152	18	0.008	0.078	0.406
37	F16033	WIRU	EUREG	27	3	8.1	2.126	0.144	0.918	0.274	0.196	0.157	20	4.3	107	585	20	0.013	0.068	0.451
38	F16034	WIRU	EUREG	27	3	3.5	1.405	0.132	0.696	0.339	0.254	0.115	23	1.9	98	902	13	0.016	0.078	0.376
39	F16035	WIRU	EUREG	27	3	0.9	0.985	0.089	0.423	0.406	0.265	0.061	26	1.3	58	971	10	0.016	0.050	0.482
40	F16037	WIRU	EUREG	28	3	8.1	1.782	0.155	0.681	0.314	0.231	0.116	19	3.9	65	331	17	0.007	0.084	0.239
41	F16038	WIRU	EUREG	28	3	4.2	1.544	0.131	0.640	0.446	0.266	0.111	17	3.6	70	593	15	0.006	0.094	0.382
42	F16039	WIRU	EUREG	28	3	1.9	1.141	0.106	0.653	0.463	0.246	0.084	27	3.2	87	790	12	0.006	0.066	0.320
43	F16053	ERIN	EUREG	34	3	8.9	2.633	0.153	0.802	0.333	0.231	0.156	21	4.5	68	1124	19	0.007	0.233	0.826
44	F16054	ERIN	EUREG	34	3	5.8	2.219	0.139	0.550	0.446	0.289	0.161	16	4.8	50	1178	21	0.006	0.206	0.726
45	F16066	RVHD	EUREG	38	3	8.5	2.442	0.147	0.574	0.635	0.289	0.170	23	6.8	90	159	22	0.009	0.266	0.999
46	F16067	RVHD	EUREG	38	3	8.5	2.815	0.165	0.943	0.443	0.250	0.186	21	7.9	74	156	23	0.008	0.280	0.999
47	F16068	RVHD	EUREG	38	3	8.5	2.184	0.123	0.579	1.134	0.360	0.160	28	5.8	97	253	20	0.012	0.386	0.999
48	F16083	TAUP	EUREG	39	3	3.3	1.458	0.124	0.477	0.537	0.352	0.130	19	4.1	50	1194	18	0.008	0.257	0.656
49	F16084	TAUP	EUREG	39	3	1.5	1.451	0.113	0.385	0.528	0.364	0.112	19	3.7	54	1277	16	0.007	0.185	0.698
50	F16124	TIRU	EUREG	54	3	7.6	2.084	0.102	0.525	0.354	0.252	0.133	17	3.6	59	886	17	0.008	0.245	0.790
51	F16137	KANG	EUREG	58	3	8.2	1.607	0.129	0.614	0.472	0.179	0.107	18	3.1	78	794	16	0.007	0.061	0.259
52	F16138	KANG	EUREG	58	3	2.9	1.933	0.132	0.648	0.372	0.160	0.123	12	4.8	63	884	20	0.012	0.094	0.295

APPENDIX TABLE 1.2 *E. saligna* : dataset used for computing DRIS norms.

	Log. no.	Forest name	Spec.	Surv. ref.	Stand age (yr)	Av Ht (m)	N	P	K	Ca	Mg	S	B	Cu	Fe	Mn	Zn	Al	Na	Cl
							------- percent ovendry weight ----						------ ppm -------					----- % OD Wt --		
1	F16049	TAKA	EUSAL	33	2	5.6	2.321	0.145	0.764	1.031	0.198	0.189	41	6.3	103	34	22	0.012	0.228	0.543
2	F16050	TAKA	EUSAL	33	2	4.1	2.169	0.127	0.751	1.237	0.234	0.203	36	6.8	107	302	23	0.016	0.372	0.728
3	F16051	TAKA	EUSAL	33	2	2.2	2.173	0.122	0.690	1.436	0.222	0.174	40	6.5	93	306	20	0.015	0.397	0.721
4	F16062	NAPR	EUSAL	37	2	4.5	3.105	0.219	0.498	0.691	0.319	0.212	32	11.3	80	1546	29	0.011	0.083	0.243
5	F16086	WARK	EUSAL	40	2	5.4	1.925	0.128	0.794	0.696	0.244	0.144	28	6.9	100	952	21	0.005	0.188	0.448
6	F16087	WARK	EUSAL	40	2	1.6	1.722	0.109	0.716	0.789	0.329	0.133	30	8.3	79	811	23	0.004	0.223	0.619
7	F16089	FISH	EUSAL	41	2	6.1	2.503	0.169	0.801	0.550	0.235	0.170	35	8.2	130	346	23	0.010	0.167	0.379
8	F16091	GLRB	EUSAL	42	2	7.1	1.958	0.141	1.051	0.654	0.217	0.132	32	8.5	81	276	19	0.005	0.155	0.600
9	F16092	GLRB	EUSAL	42	2	3.7	1.421	0.111	0.815	0.941	0.257	0.134	37	6.7	91	474	18	0.009	0.153	0.614
10	F16098	CARS	EUSAL	44	2	7.9	2.262	0.138	0.867	0.552	0.235	0.164	31	6.8	98	1098	21	0.008	0.123	0.345
11	F16099	CARS	EUSAL	44	2	4.4	2.122	0.136	0.950	1.114	0.316	0.143	36	8.0	76	1628	24	0.011	0.117	0.400
12	F16100	CARS	EUSAL	44	2	3.6	1.545	0.130	0.702	0.698	0.419	0.128	32	7.4	176	1550	21	0.019	0.151	0.612
13	F16106	AUPO	EUSAL	47	2	9.5	2.080	0.176	0.888	0.597	0.301	0.152	37	8.3	72	733	22	0.004	0.126	0.382
14	F16107	AUPO	EUSAL	47	2	4.6	2.279	0.164	0.826	0.675	0.336	0.176	29	7.2	78	1229	23	0.008	0.137	0.386
15	F16114	ROEU	EUSAL	50	2	6.0	2.147	0.133	0.885	0.783	0.342	0.146	33	7.6	76	1204	29	0.019	0.116	0.399
16	F16115	ROEU	EUSAL	50	2	2.7	2.119	0.118	0.638	1.285	0.426	0.145	50	7.5	78	2401	24	0.015	0.091	0.447
17	F16122	TIRU	EUSAL	53	2	4.4	1.770	0.098	0.592	1.082	0.442	0.137	40	6.0	104	974	23	0.026	0.167	0.564
18	F16123	TIRU	EUSAL	53	2	1.7	1.470	0.081	0.528	0.932	0.454	0.119	40	7.1	59	693	22	0.012	0.173	0.601
19	F16125	TANE	EUSAL	55	2	8.1	2.307	0.142	0.876	0.337	0.189	0.162	18	2.4	70	165	18	0.007	0.121	0.695
20	F16126	TANE	EUSAL	55	2	3.4	1.392	0.132	0.588	0.566	0.274	0.109	19	3.5	73	480	17	0.009	0.108	0.507
21	F16061	NAPR	EUSAL	37	3	4.5	3.105	0.213	0.682	0.719	0.270	0.219	26	7.3	125	1474	27	0.013	0.166	0.350
22	F16069	RVHD	EUSAL	38	3	6.5	2.298	0.139	0.824	0.607	0.266	0.160	39	7.0	75	199	22	0.008	0.196	0.438
23	F16070	RVHD	EUSAL	38	3	6.5	2.654	0.137	0.680	0.630	0.275	0.190	38	11.7	81	263	26	0.011	0.193	0.559
24	F16071	RVHD	EUSAL	38	3	6.5	3.041	0.170	0.756	0.724	0.268	0.223	32	11.4	107	130	28	0.012	0.207	0.695
25	F16094	MCIN	EUSAL	43	3	9.3	2.133	0.142	0.772	0.822	0.281	0.150	45	12.7	84	1382	23	0.007	0.129	0.304
26	F16095	MCIN	EUSAL	43	3	5.0	2.233	0.154	0.677	0.734	0.405	0.166	32	9.5	85	570	21	0.004	0.161	0.405
27	F16096	MCIN	EUSAL	43	3	3.1	2.391	0.157	0.703	0.835	0.427	0.181	36	11.0	59	1117	21	0.007	0.145	0.392
28	F16102	AUPO	EUSAL	45	3	9.5	1.937	0.153	0.662	0.908	0.342	0.137	38	5.8	108	1099	18	0.008	0.147	0.325
29	F16103	AUPO	EUSAL	45	3	4.9	2.089	0.153	0.582	0.964	0.455	0.146	39	6.4	89	2243	20	0.009	0.113	0.382
30	F16109	AUPO	EUSAL	48	3	9.5	1.938	0.143	0.679	0.827	0.345	0.136	38	6.4	55	724	21	0.008	0.175	0.421
31	F16110	OTGA	EUSAL	49	3	5.7	2.243	0.151	0.769	1.064	0.273	0.160	32	8.8	112	998	23	0.010	0.122	0.328
32	F16111	OTGA	EUSAL	49	3	5.6	2.029	0.139	0.794	1.013	0.255	0.155	28	6.5	78	951	24	0.010	0.145	0.415
33	F16117	CORO	EUSAL	52	3	7.5	1.342	0.085	0.640	0.596	0.269	0.140	40	3.9	66	1110	16	0.013	0.254	0.613
34	F16118	CORO	EUSAL	52	3	3.2	1.590	0.077	0.579	0.726	0.339	0.125	37	5.1	76	1862	17	0.012	0.201	0.580

APPENDIX TABLE 1.3 *E.delegatensis*: dataset used for computing DRIS norms.

	Log. no.	Forest name	Sp.	Surv. ref. no.	Stand age (yrs)	Av. ht (m)	N	P	K	Ca	Mg	S	B	Cu	Fe	Mn	Zn	Al	Na	Cl
							------- percent ovendry weight -----						---- ppm --------					--- percent --		
1	F15955	ORET	EUDEL	1	2	3.4	2.039	0.135	0.615	0.293	0.194	0.130	16	4.0	62	143	19	0.006	0.018	0.278
2	F16153	ORET	EUDEL	2	2	7.5+	2.163	0.166	0.749	0.302	0.207	0.146	17	5.4	91	114	22	0.006	0.028	0.363
3	F15972	WIKA	EUDEL	6	2	3.0	2.029	0.130	0.565	0.702	0.255	0.135	16	3.1	62	291	24	0.007	0.114	0.529
4	F15978	TATU	EUDEL	8	2	3.4	1.570	0.103	0.553	0.402	0.200	0.096	14	1.8	62	705	18	0.005	0.050	0.303
5	F15988	HERB	EUDEL	12	2	4.0	2.205	0.121	0.724	0.283	0.191	0.143	28	3.1	70	932	20	0.011	0.051	0.293
6	F15989	HERB	EUDEL	12	2	2.3	1.108	0.092	0.520	0.345	0.261	0.123	23	2.1	68	1450	14	0.016	0.061	0.308
7	F15990	HERB	EUDEL	12	2	1.0	0.843	0.077	0.414	0.410	0.364	0.094	23	1.3	79	2104	11	0.019	0.058	0.321
8	F16001	NASB	EUDEL	14	2	2.2	1.418	0.129	0.898	0.347	0.200	0.123	18	3.4	64	588	17	0.011	0.010	0.277
9	F16165	BALM	EUDEL	18	2	0.9	1.106	0.096	0.540	0.272	0.214	0.109	19	3.7	84	334	15	0.009	0.007	0.404
10	F16008	GDNS	EUDEL	21	2	6.5	2.057	0.146	0.797	0.262	0.166	0.154	29	2.4	67	385	23	0.005	0.006	0.164
11	F16009	GDNS	EUDEL	21	2	3.8	1.193	0.103	0.553	0.389	0.207	0.099	28	2.0	61	409	17	0.004	0.006	0.098
12	F16010	GDNS	EUDEL	21	2	2.1	1.173	0.156	0.591	0.435	0.245	0.087	30	2.4	94	839	16	0.004	0.007	0.093
13	F16014	KORE	EUDEL	22	2	5.2	1.295	0.106	0.560	0.290	0.162	0.099	22	1.6	38	156	15	0.003	0.006	0.177
14	F16015	KORE	EUDEL	22	2	2.6	1.083	0.083	0.413	0.396	0.216	0.082	23	0.8	33	211	14	0.002	0.006	0.097
15	F16016	KORE	EUDEL	22	2	1.4	1.006	0.095	0.461	0.382	0.198	0.067	22	1.7	44	243	14	0.003	0.006	0.080
16	F15953	ORET	EUDEL	1	3	6.1	2.569	0.127	0.827	0.264	0.179	0.163	25	4.0	82	142	28	0.006	0.020	0.245
17	F15954	ORET	EUDEL	1	3	2.7	1.489	0.118	0.754	0.382	0.210	0.105	17	4.2	78	220	17	0.009	0.017	0.304
18	F15960	LONG	EUDEL	4	3	6.4	1.522	0.100	0.875	0.305	0.187	0.124	20	2.4	40	623	18	0.005	0.019	0.377
19	F15962	LONG	EUDEL	4	3	2.5	1.171	0.095	0.589	0.343	0.230	0.094	19	2.1	55	478	16	0.007	0.048	0.413
20	F15965	MACL	EUDEL	5	3	5.9	1.765	0.118	0.714	0.381	0.207	0.156	20	3.8	57	587	17	0.008	0.044	0.455
21	F15971	MACL	EUDEL	5	3	1.7	0.944	0.080	0.438	0.324	0.222	0.085	18	1.4	50	579	13	0.006	0.037	0.355
22	F15974	MKOR	EUDEL	7	3	5.7	2.045	0.144	0.798	0.357	0.186	0.140	14	3.7	68	385	24	0.006	0.103	0.525
23	F15975	MKOR	EUDEL	7	3	2.8	1.073	0.084	0.568	0.329	0.208	0.080	13	1.6	69	418	15	0.005	0.046	0.298
24	F15976	TATU	EUDEL	8	3	6.1	2.026	0.129	0.812	0.364	0.178	0.142	14	3.6	73	282	24	0.005	0.031	0.345
25	F15982	BEAU	EUDEL	10	3	8.2	1.693	0.110	0.943	0.365	0.191	0.151	32	2.2	63	988	20	0.010	0.020	0.476
26	F15983	BEAU	EUDEL	10	3	3.2	0.933	0.070	0.515	0.519	0.247	0.075	28	1.0	71	2129	13	0.012	0.013	0.485
27	F15985	GDHU	EUDEL	11	3	4.3	1.618	0.093	0.632	0.233	0.164	0.112	14	1.6	62	589	16	0.008	0.031	0.254
28	F15986	GDHU	EUDEL	11	3	2.4	0.930	0.076	0.559	0.276	0.206	0.084	13	2.2	42	859	12	0.005	0.024	0.197
29	F15998	NASB	EUDEL	13	3	4.1	1.536	0.119	0.842	0.280	0.172	0.131	39	3.7	68	349	18	0.009	0.008	0.255
30	F15999	NASB	EUDEL	13	3	1.5	0.916	0.072	0.552	0.344	0.248	0.085	53	1.2	61	311	13	0.011	0.006	0.206
31	F16000	NASB	EUDEL	13	3	3.0	1.015	0.164	1.014	0.916	0.418	0.122	74	2.9	85	968	12	0.014	0.006	0.358
32	F16163	BALM	EUDEL	16	3	3.0	1.035	0.104	0.536	0.278	0.212	0.098	20	2.4	68	355	16	0.010	0.010	0.405
33	F16002	GDNS	EUDEL	19	3	2.7	1.076	0.138	0.604	0.431	0.227	0.082	22	2.1	52	638	16	0.004	0.010	0.209
34	F16005	GDNS	EUDEL	20	3	4.9	2.018	0.127	0.580	0.360	0.195	0.131	22	2.2	63	601	21	0.009	0.008	0.217
35	F16006	GDNS	EUDEL	20	3	2.5	1.540	0.130	0.524	0.403	0.215	0.064	26	1.7	52	630	16	0.004	0.004	0.158
36	F16007	GDNS	EUDEL	20	3	1.5	1.292	0.153	0.530	0.377	0.229	0.060	27	1.3	40	861	15	0.004	0.005	0.235
37	F16024	GDNS	EUDEL	24	3	7.2	1.834	0.132	0.846	0.340	0.182	0.141	25	4.0	55	694	21	0.003	0.006	0.324
38	F16025	GDNS	EUDEL	24	3	2.6	1.283	0.114	0.574	0.446	0.256	0.108	30	3.0	62	936	16	0.004	0.011	0.448
39	F16031	WIRU	EUDEL	26	3	7.0	2.061	0.171	1.110	0.202	0.166	0.144	13	2.9	55	154	22	0.006	0.022	0.263
40	F16080	TAUP	EUDEL	39	3	4.0	1.494	0.128	0.575	0.437	0.233	0.097	16	1.8	60	723	14	0.009	0.346	0.889
41	F16135	KANG	EUDEL	58	3	5.8	2.133	0.123	0.650	0.345	0.156	0.138	16	3.9	50	319	18	0.007	0.015	0.240
42	F16136	KANG	EUDEL	58	3	2.2	1.418	0.065	0.513	0.398	0.169	0.096	16	2.8	51	500	14	0.009	0.014	0.216

APPENDIX TABLE 2.1- *E. regnans* : nutrient ratios selected as important for DRIS, shown with criteria for selection, provisional DRIS standards and [3]variance ratios

Nut. ratio	[1]Criteria for ratio selection	[2]DRIS standards Mean $\overline{X}$	Std.Dev SD	[3]Variance ratio (S^2_L/S^2_H)	Sig.	Nut. ratio	[1]Criteria for ratio selection	[2]DRIS standards Mean $\overline{X}$	Std.Dev. SD	[3]Variance ratio (S^2_L/S^2_H)	Sig.
(1) N/P	m	2.647	0.2714	1.873	ns	(18) S/B	m	-4.942	0.2593	1.773	ns
(2) N/K	m	1.0457	0.2894	0.945	ns	(19) S/Fe	v	-6.259	0.2046	2.594	*
(3) N/Ca	m	1.513	0.3614	0.763	ns	(20) S/Mn	m	-8.112	0.9950	0.579	ns
(4) N/Mg	m	2.091	0.2941	1.760	ns	(21) S/Zn	m,v	-4.870	0.0687	6.410	**
(5) N/S	m,v	2.633	0.1349	2.463	*	(22) S/Al	m	2.911	0.3623	1.359	ns
(6) N/B	m	-2.309	0.2826	1.548	ns	(23) Cu/Fe	v	-2.960	0.3878	2.113	*
(7) N/Fe	m	-3.626	0.2514	1.779	ns	(24) Cu/Mn	m	-4.813	1.170	0.691	ns
(8) N/Mn	m	-5.479	0.9948	0.678	ns	(25) Cu/Zn	m,v	-1.571	0.2970	2.392	*
(9) N/Zn	m	-2.237	0.1436	1.400	ns	(26) Cu/Al	m,v	6.210	0.5012	1.980	*
(10) N/Al	m	5.544	0.4057	1.418	ns	(27) Fe/Mn	m	-1.852	1.0199	0.451	ns
(11) N/Cl	m	1.330	0.5190	0.786	ns	(28) Fe/Zn	v	1.390	0.2070	2.134	*
(12) P/Mg	m	-0.5561	0.4111	0.777	ns	(29) Fe/Al	m	9.170	0.3481	1.083	ns
(13) K/Ca	m	0.4674	0.4334	0.587	ns	(30) Zn/Al	m	7.781	0.3496	1.718	ns
(14) K/Mg	m	1.0457	0.3947	0.765	ns	(31) Na/Cl	v	-1.347	0.3044	2.065	*
(15) K/B	m	-3.355	0.2804	1.025	ns						
(16) K/Mn	m	-6.524	1.0068	0.619	ns						
(17) K/Al	m	4.498	0.4294	1.152	ns						

1 m signifies that the mean for 'high' 'MAI' subgroup ($\overline{X}_H$) was significantly greater (p≤p.05) than the mean for 'low' MAI subgroup ($\overline{X}_L$)

v signifies that the variance in the 'low' 'MAI' subgroup was significantly greater (p≤0.05) than that in the 'high' 'MAI" subgroup (with $\overline{X}_L < \overline{X}_H$)

2 After log transformation

3 Based on variances for 26 observations in the 'high' MAI subgroup (S^2_H) and 26 in the low (S^2_L), i.e. a total of 52 observations. The critical values of F for significance at the 5% (*) and 1% (**) levels are 1.95 and 2.60 respectively.

APPENDIX TABLE 2.2 - *E. saligna* : nutrient ratios selected as important for DRIS, shown with criteria for selection, provisional DRIS standards and [3]variance ratios

	Nutrient ratio	[1]Criteria for ratio selection	[2]DRIS Standards [2]Mean $\overline{X}$	[2]Std.Dev SD	[3]Variance ratio (S^2_L/S^2_H)	Sig.
(1)	N/Ca	m	1.1248	0.3362	1.234	ns
(2)	P/Mg	m	-0.6349	0.2650	2.207	ns
(3)	P/B	m	-5.469	0.3061	1.547	ns
(4)	K/Ca	m	0.1744	0.3585	0.608	ns
(5)	K/Mg	m	1.1016	0.2945	1.370	ns
(6)	K/Cu	m	-2.102	0.3954	0.596	ns
(7)	K/Fe	m	-4.653	0.2650	1.038	ns
(8)	K/Zn	m	-3.267	0.1645	1.590	ns
(9)	K/Al	m	4.600	0.4891	1.013	ns
(10)	K/Cl	m	0.6108	0.2739	1.289	ns

1 m signifies that the mean for 'high' MAI subgroup ($\overline{X}_H$) is significantly ($p \geq 0.05$) greater than the mean for 'low' MAI subgroup ($\overline{X}_L$)

v signifies that the variance in the 'low' 'MAI' subgroup was significantly greater ($p \geq 0.05$) than that in the 'high' 'MAI' subgroup (with $\overline{X}_L < \overline{X}_H$)

2 After log transformation

3 Based on variances for 13 observations in the 'high' MAI subset (S^2_H) and 21 in the 'low' (S^2_L), i.e. a total of 34 observations; the critical value of F for significance at the 5% level (*) is 2.54.

APPENDIX TABLE 2.3 - *E. delegatensis* ratios selected as important for DRIS, shown with criteria for selection, provisional DRIS standards and variance ratios

Nut. ratio	[1]Criteria for ratio selection	[2]DRIS standards Mean $\overline{X}$	Std.Dev SD	[3]Variance ratio (S^2_L/S^2_H)	Sig.
(1) N/P	m,v	2.698	0.1423	3.258	**
(2) N/K	m	0.9506	0.2270	0.979	ns
(3) N/Ca	m	1.724	0.3493	1.061	ns
(4) N/Mg	m,v	2.296	0.2326	2.293	*
(5) N/S	v	2.638	0.1181	4.365	**
(6) N/B	m	-2.360	0.3824	1.673	ns
(7) N/Cu	v	-0.4599	0.2391	2.672	*
(8) N/Fe	m	-3.483	0.1811	3.168	**
(9) N/Mn	m	-5.251	0.7685	0.847	ns
(10) N/Zn	m	-2.389	0.1236	1.175	ns
(11) N/Al	m,v	5.764	0.3113	3.939	**
(12) N/Cl	m	1.862	0.4094	1.952	ns
(13) P/Mg	m,v	-0.4026	0.2018	2.278	*
(14) P/B	m	-4.049	0.3753	1.219	ns
(15) P/Fe	m,v	-6.182	0.1917	2.970	*
(16) P/Mn	m	-7.950	0.7870	0.756	ns
(17) P/Al	m,v	3.066	0.3827	3.228	**
(18) K/Ca	m	0.7733	0.4059	0.574	ns
(19) K/Mg	m	1.345	0.2711	1.205	ns
(20) K/B	m	-3.311	0.3514	1.326	ns
21) K/Fe	m	-4.434	0.2807	0.835	ns
(22) K/Mn	m	-6.202	0.7228	0.903	ns
(23) K/Al	m	4.813	0.3921	1.902	ns
(24) Ca/Mn	m	-6.975	0.6608	1.230	ns
(25) S/B	m	-4.998	0.3154	2.025	ns
(26) S/Fe	m	-6.121	0-.1977	1.326	ns
(27) S/Mn	m	-7.890	0.7205	0.854	ns
(28) S/Al	m,v	3.126	0.3109	2.331	*
(29) S/Zn	v	-5.027	0.1309	2.887	*
(30) Cu/Fe	m	3.023	0.2903	1.741	ns
(31) Cu/Mn	m	-4.792	0.8715	0.913	ns
(32) Cu/Al	m	6.224	0.4412	1.977	ns
(33) Cu/Cl	v	2.322	0.4197	2.244	*
(34) Fe/Mn	m	-1.768	0.7608	0.659	ns
(35) Zn/Al	m,v	8.153	0.3568	2.926	*

1 m signifies that the mean for the 'high' 'MAI' subgroup ($\overline{X}_H$) was significantly greater ($p \leq 0.05$) from the mean for the 'low' 'MAI' ($\overline{X}_L$) subgroup

v signifies that the variance in the 'low' MAI subgroup was significantly greater ($p \leq 0.05$) than the variance in the 'high' MAI subgroup (with $\overline{X}_L < \overline{X}_H$)

2 After log transformation

3 Based on 18 observations in the 'high' subgroup (S^2_H) and 24 in the 'low', (S^2_L) i.e. a total of 42 observations; the critical values of F for significance at the 5% (*) and 1% level (**) are 2.20 and 3.10 respectively.

APPENDIX TABLE 3.1 - List of formulae used to compute 14 DRIS indices for the *E. regnans* 'standard' dataset (52 observations)

(1) $$\text{N-index} = \frac{f(N/P) + f(N/K) + f(N/Ca) + f(N/Mg) + f(N/S) + f(N/B) + f(N/Fe) + f(N/Mn) + f(N/Zn) + f(N/Al) + f(N/Cl)}{11}$$

(2) $$\text{P-index} = \frac{-f(N/P) + f(P/Mg)}{2}$$

(3) $$\text{K-index} = \frac{-f(N/K) + f(K/Ca) + f(K/Mg) + f(K/B) + f(K/Mn) + f(K/Al)}{6}$$

(4) $$\text{Ca-index} = \frac{-f(N/Ca) - f(K/Ca)}{2}$$

(5) $$\text{Mg-index} = \frac{-f(N/Mg) - f(P/Mg) - f(K/Mg)}{3}$$

(6) $$\text{S-index} = \frac{-f(N/S) + f(S/B) + f(S/Fe) + f(S/Mn) + f(S/Zn) + f(S/Al)}{6}$$

(7) $$\text{Al-index} = \frac{-f(N/Al) - f(K/Al) - f(S/Al) - f(Cu/Al) - f(Fe/Al) - f(Zn/Al)}{6}$$

(8) $$\text{Na-index} = f(Na/Cl)$$

(9) $$\text{Cl-index} = \frac{-f(N/Cl) - f(Na/Cl)}{2}$$

(10) $$\text{B-index} = \frac{-f(N/B) - f(K/B) - f(S/B)}{3}$$

(11) $$\text{Cu-index} = \frac{f(Cu/Mn) + f(Cu/Zn) + f(Cu/Al) + f(Cu/Fe)}{4}$$

(12) $$\text{Fe-index} = \frac{-f(N/Fe) - f(S/Fe) - f(Cu/Fe) + f(Fe/Mn) + f(Fe/Al) + f(Fe/Zn)}{6}$$

(13) $$\text{Mn-index} = \frac{-f(K/Mn) - f(S/Mn) - f(Cu/Mn) - f(Fe/Mn) + f(N/Mn)}{5}$$

(14) $$\text{Zn-index} = \frac{-f(N/Zn) - f(S/Zn) - f(Cu/Zn) - f(Fe/Zn) + f(Zn/Al)}{5}$$

APPENDIX TABLE 3.2 - List of formulae used to compute 11 DRIS indices for the *E. saligna* 'standards' dataset (34 observations)

(1) N-index = $f(N/Ca)$

(2) P-index = $\frac{f(P/Mg) + f(P/B)}{2}$

(3) K-index = $\frac{f(K/Ca) + f(K/Mg) + f(K/Cu) + f(K/Fe) + f(K/Zn) + f(K/Al) + f(K/Cl)}{7}$

(4) Ca-index = $\frac{-f(N/Ca) - f(K/Ca)}{2}$

(5) Mg-index = $\frac{-f(P/Mg) - f(K/Mg)}{2}$

(6) Al-index = $-f(K/Al)$

(7) Cl-index = $-f(K/Cl)$

(8) B-index = $-f(P/B)$

(9) Cu-index = $-f(K/Cu)$

(10) Fe-index = $-f(K/Fe)$

(11) Zn-index = $-f(K/Zn)$

APPENDIX TABLE 3.3 - List of formulae used to compute 13 DRIS indices for the survey-based *E. delegatensis* 'standards' dataset (42 observations)

(1) N-index = $\frac{f(N/P)+f(N/K)+f(N/Ca)+f(N/Mg)+f(N/S)+f(N/B)+f(N/Cu)+f(N/Fe)+f(N/Mn)+f(N/Zn)+f(N/Al)+f(N/Cl)}{12}$

(2) P-index = $\frac{-f(N/P)+f(P/Mg)+f(P/B)+f(P/Fe)+f(P/Mn)+f(P/Al)}{6}$

(3) K-index = $\frac{-f(N/K)+f(K/Ca)+f(K/Mg)+f(K/B)+f(K/Fe)+f(K/Mn)+f(K/Al)}{7}$

(4) Ca-index = $\frac{-f(N/Ca)-f(K/Ca)+f(Ca/Mn)}{3}$

(5) Mg-index = $\frac{-f(N/Mg)-f(P/Mg)-f(K/Mg)}{3}$

(6) S-index = $\frac{-f(N/S)+f(S/B)+f(S/Fe)+f(S/Mn)+f(S/Zn)+f(S/Al)}{6}$

(7) Al-index = $\frac{-f(N/Al)-f(P/Al)-f(K/Al)-f(S/Al)-f(Cu/Al)-f(Zn/Al)}{6}$

(8) B-index = $\frac{-f(N/B)-f(P/B)-f(K/B)-f(S/B)}{4}$

(9) Cl-index = $\frac{-f(N/Cl)-f(Cu/Cl)}{2}$

(10) Cu-index = $\frac{-f(N/Cu)+f(Cu/Fe)+f(Cu/Mn)+f(Cu/Al)+f(Cu/Cl)}{5}$

(11) Fe-index = $\frac{-f(N/Fe)-f(P/Fe)-f(K/Fe)-f(S/Fe)-f(Cu/Fe)+f(Fe/Mn)}{6}$

(12) Mn-index = $\frac{-f(N/Mn)-f(P/Mn)-f(K/Mn)-f(Ca/Mn)-f(S/Mn)-f(Cu/Mn)-f(Fe/Mn)}{7}$

(13) Zn-index = $\frac{-f(N/Zn)-f(S/Zn)+f(Zn/Al)}{3}$

APPENDIX 4 - DRIS indices and sums for 'standards' datasets

APPENDIX TABLE 4.1 -Estimated mean annual increment (MAI), 'yield' category (high or low), DRIS indices, and corresponding absolute sum of DRIS indices for each sample in the <u>E.regnans</u> 'standards' dataset

#	MAI	Subset	N	P	K	Ca	Mg	S	Al	Na	Cl	B	Cu	Fe	Mn	Zn	Sum of
	(m)		DRIS Index														indices
1	3.7	H	0.94	0.37	0.86	-0.90	-0.84	0.67	-1.43	-0.95	0.33	-1.08	1.25	0.26	-1.69	-0.38	11.94
2	2.4	H	0.17	0.10	0.07	-0.13	0.06	0.21	-1.30	0.14	-0.23	-0.44	0.05	0.33	0.44	0.26	3.94
3	2.7	H	-0.13	-1.90	0.10	-0.52	0.38	0.00	1.11	1.29	-0.36	-0.26	-1.70	0.58	0.23	0.05	8.61
4	1.8	L	-1.61	-1.29	-0.35	0.78	1.76	0.69	0.89	0.93	0.15	0.76	-0.44	-0.07	0.47	0.49	10.68
5	0.6	L	-2.84	-0.15	-0.97	1.67	2.55	1.46	2.79	0.51	0.89	1.14	-2.13	-0.03	1.36	-0.60	19.08
6	2.6	H	0.08	-0.76	-1.04	0.32	1.17	-0.29	1.87	-0.10	0.43	-1.28	-1.09	-0.04	0.46	-0.28	9.21
7	3.2	H	0.65	1.47	0.52	-0.84	-0.97	0.31	-1.47	1.61	-2.43	0.01	-0.46	0.18	-0.18	0.65	11.74
8	1.8	L	-1.24	1.07	0.07	0.38	0.60	-0.32	1.19	-1.73	0.85	1.02	-0.99	-0.55	0.44	1.07	11.52
9	0.8	L	-2.27	1.87	-0.72	1.81	1.76	-1.74	1.73	-2.81	1.84	1.89	-1.65	1.29	1.12	0.68	23.16
10	3.3	H	0.06	0.44	0.06	-0.36	-0.70	-0.37	-0.68	-0.96	-0.02	0.85	-1.09	1.15	1.20	-0.59	8.53
11	2.0	H	-1.38	0.56	-0.66	1.62	0.67	-0.86	0.77	-2.65	1.73	2.26	-1.72	-0.46	2.19	0.88	18.43
12	1.2	L	-1.86	0.08	-0.14	1.22	1.36	-1.48	0.82	-2.69	2.08	1.14	-2.18	1.08	1.78	1.41	19.32
13	0.7	L	-3.24	1.70	-0.76	2.27	2.31	-1.07	1.69	-2.79	2.43	1.96	-3.40	1.40	2.40	1.38	28.79
14	3.5	H	0.33	1.30	0.96	-0.71	-0.94	0.53	-1.09	0.51	-0.96	-0.74	0.65	0.79	-1.46	-0.16	11.14
15	1.7	L	0.36	0.72	0.32	0.11	-0.13	-0.86	-1.22	-0.14	-0.34	0.11	1.02	-0.96	-0.25	1.76	8.30
16	0.9	L	-1.46	1.67	-0.44	1.61	1.04	-2.76	0.69	-0.90	0.68	2.06	-0.64	1.07	0.28	1.90	17.21
17	2.2	H	-1.03	-1.46	-0.22	0.75	1.66	-1.03	0.80	-0.95	0.90	1.48	-0.46	-0.74	1.09	1.21	13.78
18	1.0	L	-0.43	-1.02	-0.13	0.33	1.54	-0.43	0.23	-0.73	0.28	-0.09	0.02	-0.31	1.10	0.05	6.69
19	2.0	H	0.25	1.17	0.65	0.37	-1.55	0.35	-0.25	1.35	-0.84	-0.82	0.36	-0.62	-0.10	-0.02	8.71
20	0.8	L	-1.15	1.25	-0.21	1.75	0.25	-1.07	0.74	1.43	-0.53	0.52	0.12	0.06	0.17	1.10	10.34
21	2.0	H	0.45	-0.31	-0.62	-0.16	0.19	-0.16	-1.08	0.45	-0.27	-0.16	0.59	0.49	0.31	0.06	5.29
22	4.3	H	-0.43	1.03	0.24	0.78	-0.48	-0.36	1.13	-0.60	0.48	-0.17	0.01	0.89	-1.18	-0.56	8.35
23	2.8	H	0.00	-1.27	-1.75	1.25	1.93	-0.23	1.34	-0.12	0.51	0.96	0.10	-0.88	0.41	-0.56	11.32
24	1.4	L	-0.64	-2.04	-2.07	2.15	2.60	0.06	0.68	-0.34	0.53	1.38	0.23	-1.40	1.15	0.76	16.04
25	3.9	H	0.35	0.05	0.48	-0.23	-0.95	0.28	-0.48	0.05	-0.42	1.03	1.44	-0.55	-1.27	-0.14	7.72
26	1.6	L	-0.22	-0.26	-0.46	1.59	0.04	-0.35	0.10	-0.30	-0.05	1.75	1.63	-0.30	-0.93	-0.20	8.19
27	0.6	L	-0.96	0.57	-0.53	0.33	0.61	-0.30	2.80	0.97	-0.35	0.19	-1.55	-0.20	0.83	-0.53	10.73
28	2.0	H	-0.56	-0.23	0.43	0.23	0.59	0.12	-0.46	-0.47	0.57	0.07	-0.34	-0.48	0.81	0.64	5.99
29	0.8	L	-0.86	-0.19	-0.10	0.33	0.90	-0.56	0.54	1.29	-0.03	1.29	-0.51	0.04	0.43	0.36	7.44
30	2.5	H	-0.75	-0.13	-0.06	-0.13	0.75	-0.15	0.63	0.73	0.10	0.28	-0.71	0.59	0.33	-0.04	5.37
31	0.6	L	-1.76	0.42	-0.53	0.92	2.11	-0.22	1.72	1.10	0.18	1.63	-1.50	-1.09	1.31	0.84	15.30
32	0.7	L	-1.74	1.06	0.65	-0.07	1.08	-0.84	1.12	-2.49	1.93	0.35	-0.39	0.12	-0.01	1.37	13.21
33	1.8	L	0.07	0.36	0.36	0.30	-0.05	1.54	0.05	0.89	-0.96	-0.65	-2.74	-0.38	-0.62	1.14	10.11
34	0.5	L	-1.87	1.84	0.42	1.44	1.00	-1.25	-0.23	-1.47	0.82	2.57	-0.60	0.12	-0.16	2.41	16.21
35	0.6	L	-1.40	0.79	0.18	0.86	1.22	-0.97	0.00	-1.56	1.00	1.35	-1.30	-0.37	1.09	2.13	14.22
36	2.3	H	-1.41	1.67	1.68	-0.97	-0.70	1.42	0.23	-0.99	0.70	-1.17	-0.48	0.74	-1.03	0.39	13.57
37	2.7	H	0.00	0.22	0.69	-1.60	-0.95	-0.28	0.89	-1.79	0.68	-0.53	-0.36	0.70	0.02	-0.61	9.33
38	1.2	L	-1.14	0.40	-0.19	-0.16	0.54	-0.70	2.36	-0.74	0.38	1.20	-1.93	1.46	0.80	-1.42	13.43
39	0.3	L	-1.52	-0.20	-1.42	1.36	1.80	-2.93	3.49	-3.02	2.10	3.48	-2.22	0.82	1.34	-0.03	25.73
40	2.7	H	0.13	0.57	0.28	-0.66	-0.10	-0.59	-0.01	0.99	-1.15	0.24	0.31	-0.04	-0.26	0.36	5.70
41	1.4	L	-0.43	0.15	0.04	0.50	0.64	-0.37	-0.25	-0.18	0.03	0.13	0.15	0.45	0.36	-0.06	3.74
42	0.6	L	-1.36	0.15	-0.03	0.99	0.92	-1.58	0.04	-0.76	0.44	2.51	-0.13	1.79	0.72	-0.41	11.84
43	3.0	H	0.87	-0.19	0.19	-1.24	-0.67	0.06	-0.49	0.27	0.03	-0.43	0.24	-0.74	0.72	-0.46	6.62
44	1.9	H	0.41	-0.44	-0.66	0.17	0.54	0.70	-0.60	0.29	0.06	-0.82	0.57	-1.73	0.92	0.68	8.58
45	2.8	H	0.28	-0.45	-0.79	0.89	0.35	0.22	-0.07	0.08	0.38	0.28	1.14	0.08	-1.23	-0.35	6.57
46	2.8	H	0.79	-0.18	0.69	-0.80	-0.73	0.72	-0.64	0.25	0.16	-0.93	1.62	-0.79	-1.38	-0.36	10.03
47	2.8	H	-0.38	-1.05	-1.32	2.50	1.23	-0.16	0.79	1.30	-0.12	1.19	0.58	0.39	-0.74	-0.77	12.53
48	1.1	L	-1.03	-0.26	-1.15	1.39	1.78	0.12	0.58	1.35	-0.16	0.75	0.20	-1.23	1.12	0.82	11.92
49	0.5	L	-0.79	-0.57	-1.66	1.60	2.14	-0.46	0.45	0.06	0.54	1.20	0.08	-0.65	1.26	0.56	12.03
50	2.5	H	0.53	-1.10	-0.70	-0.27	0.52	-0.07	0.38	0.58	0.06	-0.22	-0.08	-0.78	0.72	-0.19	6.19
51	2.7	H	-0.23	0.51	-0.08	0.63	-0.46	-1.04	0.13	-0.32	-0.32	0.39	-0.44	0.71	0.65	0.32	6.22
52	1.0	L	0.34	0.38	0.10	-0.29	-1.05	-0.84	1.19	0.67	-0.86	-1.55	0.17	-0.89	0.65	0.71	9.69

APPENDIX TABLE 4.2 – Estimated mean annual increment (MAI), 'yield' subset (high or low), individual DRIS indices , and absolute sum of indices for each sample in the E. saligna 'standards' dataset

#	MAI (m)	Subset	N	P	K	Ca	Mg	Al	Cl	B	Cu	Fe	Zn	Sum of indices
			DRIS Index											
1	2.8	H	-0.93	0.32	-0.56	1.13	-1.03	0.91	0.98	0.57	0.02	0.95	0.57	7.98
2	2.0	L	-1.68	-0.25	-1.10	1.78	-0.15	1.54	2.12	0.58	0.26	1.15	0.94	11.54
3	1.1	L	-2.11	-0.46	-1.19	2.33	-0.12	1.58	2.39	1.06	0.36	0.94	0.61	13.14
4	2.2	L	1.12	1.28	-1.98	0.14	0.63	1.61	-0.39	-1.58	2.58	1.61	4.85	17.77
5	2.7	H	-0.32	0.11	0.01	0.22	-0.11	-0.96	0.14	-0.26	0.15	0.69	0.05	3.03
6	0.8	L	-1.02	-1.13	-0.67	0.89	1.44	-1.20	1.70	0.49	0.88	0.19	1.23	10.84
7	3.0	H	1.16	0.80	-0.25	-0.86	-0.79	0.44	-0.50	-0.44	0.57	1.65	0.55	8.00
8	3.5	H	-0.08	0.46	1.04	-0.37	-1.19	-1.53	0.18	-0.14	-0.03	-1.16	-2.26	8.45
9	1.9	L	-2.12	-0.94	-0.19	1.51	0.30	0.19	1.20	1.11	0.01	0.23	-1.05	8.85
10	4.0	H	0.85	0.28	0.44	-0.81	-0.54	-0.17	-1.13	-0.18	-0.11	0.28	-0.48	5.28
11	2.2	L	-1.43	-0.57	0.13	1.18	0.39	0.29	-0.93	0.36	0.07	-1.02	-0.23	6.61
12	1.8	L	-0.98	-1.07	-1.56	0.73	2.00	2.03	1.73	0.12	0.64	3.29	0.80	14.95
13	4.8	H	0.37	0.38	0.57	-0.49	-0.15	-1.64	-0.85	-0.39	0.34	-0.97	-0.35	6.51
14	2.3	H	0.27	0.32	-0.02	-0.17	0.50	-0.08	-0.55	-0.96	0.16	-0.40	0.36	3.79
15	3.0	H	-0.35	-0.66	-0.32	0.25	0.84	1.55	-0.68	0.15	0.12	-0.76	1.35	7.02
16	1.4	L	-1.86	-2.17	-1.60	2.15	2.41	1.74	0.93	1.90	0.92	0.58	2.19	18.44
17	2.2	L	-1.88	-2.53	-2.12	2.03	3.02	3.02	2.05	1.77	0.54	1.94	2.39	23.30
18	0.9	L	-1.99	-3.25	-2.00	2.03	3.67	1.67	2.70	2.40	1.26	0.24	2.81	24.02
19	4.1	H	2.38	1.68	1.14	-2.27	-1.39	-0.47	1.39	-2.05	-2.77	-1.03	-1.48	18.05
20	1.7	L	-0.67	0.64	-0.64	0.53	0.75	0.86	1.69	-1.63	-0.81	0.63	0.59	9.44
21	1.5	L	1.01	1.84	-1.09	-0.18	-0.45	1.31	-0.21	-2.17	0.68	2.10	2.50	13.54
22	2.2	L	0.61	-0.30	0.13	-0.49	-0.02	-0.07	-0.08	0.55	0.09	-0.54	0.11	2.99
23	2.2	L	0.93	-0.37	-1.15	-0.32	0.45	0.97	1.51	0.51	1.88	0.48	2.29	10.88
24	2.2	L	0.92	0.72	-1.17	-0.27	-0.23	0.93	1.92	-0.75	1.55	1.13	2.10	11.70
25	3.1	H	-0.51	-0.56	-0.32	0.59	0.24	-0.21	-1.17	0.95	1.77	0.14	0.77	7.24
26	1.7	L	-0.04	-0.41	-0.72	0.38	1.62	-1.09	0.35	-0.43	1.36	0.68	1.02	8.10
27	1.0	L	-0.22	-0.63	-0.67	0.60	1.71	-0.02	0.10	-0.11	1.64	-0.84	0.79	7.33
28	3.2	H	-1.09	-0.40	-0.71	1.23	1.07	0.38	-0.37	0.15	0.17	1.67	0.22	7.45
29	1.6	L	-1.05	-0.98	-1.46	1.47	2.31	0.88	0.69	0.24	0.75	1.42	1.64	12.88
30	3.2	H	-0.81	-0.65	-0.53	0.93	1.18	0.33	0.49	0.37	0.36	-0.98	1.00	7.62
31	1.9	L	-1.13	0.26	-0.59	1.26	0.03	0.53	-0.88	-0.37	0.85	1.24	0.80	7.94
32	1.9	L	-1.28	0.32	-0.28	1.23	-0.11	0.46	-0.14	-0.53	0.00	-0.25	0.86	5.47
33	2.5	H	-0.93	-2.09	-0.50	0.61	1.37	1.44	2.07	2.24	-0.75	-0.07	-0.29	12.37
34	1.1	L	-1.01	-2.75	-1.21	1.07	2.56	1.48	2.24	2.31	0.19	0.84	0.68	16.35

APPENDIX TABLE 4.3 - Estimated mean annual increment (MAI), 'yield' subset (high Or low), individual DRIS indices, and corresponding absolute sum of indices for each sample in the *E. delegatensis* 'standards' dataset

#	MAI (m)	Subset	N	P	K	Ca	Mg	S	Al	Cl	B	Cu	Fe	Mn	Zn	Sum of indices
			DRIS Index													
1	1.7	H	0.53	0.41	-0.26	0.22	0.09	0.13	-0.01	-0.57	-0.57	0.94	0.08	-1.23	-0.62	5.66
2	3.7	H	0.07	0.80	0.08	0.18	-0.30	0.12	-0.47	-0.36	-0.81	1.36	1.05	-1.77	-0.17	7.52
3	1.5	H	-0.09	-0.17	-1.15	1.92	1.44	-0.23	0.44	1.29	-0.51	-0.28	0.13	-0.42	0.60	8.67
4	1.7	H	-0.12	-0.58	-0.73	0.47	1.17	-1.10	0.27	0.91	-0.28	-1.31	0.98	1.13	0.70	9.75
5	2.0	H	0.34	-1.12	-0.68	-1.02	-0.11	-0.74	1.63	-0.24	0.84	-0.62	0.15	1.24	-1.32	10.05
6	1.1	L	-2.28	-1.81	-1.60	0.14	3.08	-0.22	3.70	1.19	1.27	-1.37	1.35	2.13	-1.63	21.77
7	0.5	L	-3.13	-2.76	-2.55	0.79	5.48	-1.13	4.94	2.19	1.95	-2.71	2.92	2.82	-1.85	35.23
8	1.1	L	-1.46	-0.02	0.46	-0.08	0.35	-0.22	1.87	0.06	-0.19	0.19	0.19	0.64	-0.75	6.48
9	0.4	L	-2.15	-1.00	-0.82	0.31	2.11	-0.32	1.88	1.17	0.78	0.48	2.24	0.10	-0.35	13.73
10	3.2	H	0.33	0.38	0.22	-0.76	-1.05	0.18	-0.66	-1.25	0.73	-0.38	0.09	0.08	0.28	6.39
11	1.9	H	-1.19	-0.36	-0.65	0.93	1.71	-0.59	-0.23	-1.61	1.83	-0.02	1.20	0.44	1.21	11.99
12	1.0	L	-1.83	0.61	-0.96	0.78	1.70	-1.68	-0.41	-1.93	1.82	0.05	2.40	1.21	1.21	16.59
13	2.6	H	-0.19	0.71	0.20	0.66	0.48	0.35	-0.95	-0.01	1.07	-0.29	-0.47	-0.67	0.49	6.54
14	1.3	L	-0.25	-0.07	-0.71	1.64	2.75	0.03	-1.35	-0.42	1.84	-1.50	0.01	-0.02	1.40	12.00
15	0.7	L	-0.99	0.18	-0.58	1.46	2.12	-1.31	-0.47	-1.69	1.76	0.26	0.76	0.00	1.74	13.33
16	2.0	H	0.94	-0.47	0.24	-0.48	-0.85	-0.07	-0.54	-1.16	0.19	0.62	0.68	-1.41	0.58	8.23
17	0.9	L	-1.06	-0.32	0.04	0.74	0.85	-0.86	1.41	-0.03	-0.08	0.85	1.35	-0.68	-0.29	8.55
18	2.1	H	-0.51	-0.35	0.89	-0.45	0.41	0.39	-0.14	1.13	0.24	-0.28	-1.35	0.93	0.13	7.21
19	0.8	L	-1.52	-0.77	-0.48	0.53	2.25	-0.78	1.39	1.83	0.80	-0.78	0.82	0.71	0.50	13.16
20	2.0	H	-0.56	-0.46	-0.28	0.12	0.61	0.83	0.83	0.86	-0.01	0.29	-0.53	0.60	-1.64	7.62
21	0.6	L	-1.81	-1.03	-1.11	0.75	3.06	-0.55	1.58	2.21	1.19	-1.52	1.23	1.21	0.20	17.45
22	1.9	H	-0.05	0.47	0.28	-0.05	-0.52	-0.05	-0.27	1.05	-1.24	0.14	0.00	-0.04	0.63	4.80
23	0.9	L	-1.39	-0.92	-0.28	0.62	2.19	-1.14	0.78	1.47	0.02	-1.25	2.26	0.62	1.06	14.00
24	2.0	H	0.11	0.17	0.45	0.15	-0.54	0.14	-0.73	0.08	-1.18	0.38	0.45	-0.45	0.79	5.62
25	2.7	H	-0.94	-1.13	0.21	-0.43	0.10	-0.05	1.54	1.67	1.22	-1.45	0.03	1.34	-0.65	10.77
26	1.1	L	-2.43	-2.72	-1.71	1.05	3.55	-2.34	3.70	3.38	2.52	-3.42	2.69	2.85	-0.09	32.46
27	1.4	L	0.17	-1.02	-0.19	-0.82	0.28	-0.45	1.57	0.59	-0.45	-1.74	0.94	0.99	-0.94	10.14
28	0.8	L	-1.69	-0.86	-0.06	0.00	2.54	-0.16	0.87	0.27	0.15	0.10	0.11	1.69	-0.05	8.57
29	1.4	L	-1.10	-0.50	0.21	-0.33	-0.20	-0.34	1.24	-0.34	1.99	0.56	0.48	-0.03	-0.58	7.89
30	0.5	L	-2.28	-2.30	-1.11	1.04	3.47	-1.43	3.29	1.12	4.17	-1.92	2.24	0.34	-0.28	24.98
31	1.0	L	-3.97	-0.37	-0.60	2.10	3.46	-0.58	2.79	1.27	3.78	-0.50	1.34	1.07	-2.20	24.03
32	1.0	L	-2.27	-0.50	-0.77	0.40	2.04	-0.74	2.37	1.77	1.00	-0.54	1.72	0.31	0.40	14.83
33	0.9	L	-1.84	1.00	-0.31	0.97	1.67	-1.12	-0.23	0.29	1.11	-0.15	0.38	1.02	1.60	11.70
34	1.6	H	0.34	-0.46	-1.07	0.02	0.30	-0.68	1.35	-0.44	0.41	-1.06	0.26	0.75	-0.37	7.51
35	0.8	L	0.18	0.31	-0.98	0.59	1.19	-2.91	-0.13	-0.57	1.69	-0.89	0.52	1.08	1.26	12.29
36	0.5	L	-0.54	1.26	-0.79	0.44	1.43	-2.76	0.06	0.92	1.84	-1.54	-0.38	1.61	1.50	15.07
37	2.4	H	-0.25	0.38	0.56	-0.40	-0.39	0.42	-2.10	-0.07	0.48	0.99	-0.89	0.80	0.73	8.47
38	0.9	L	-1.62	-0.44	-0.94	0.72	2.31	-0.44	-0.50	1.49	1.82	0.08	0.60	1.39	0.42	12.80
39	2.3	H	0.42	1.65	1.84	-1.16	-1.72	0.61	-0.38	-0.33	-1.82	0.16	-0.89	-1.16	0.00	12.15
40	1.3	L	-0.80	-0.08	-0.95	0.66	1.49	-1.02	1.94	3.57	-0.05	-2.03	0.67	1.11	-1.29	15.66
41	1.9	H	0.82	0.12	-0.17	0.09	-0.83	0.34	0.41	-0.95	-0.62	0.80	-0.99	-0.17	-1.37	7.68
42	0.7	L	-0.20	-2.22	-0.90	0.78	1.44	-0.77	2.15	-0.31	0.52	0.07	0.56	0.76	-1.13	11.82

APPENDIX 5 - Scatterplots of yield index ('MAI') on absolute sum of DRIS indices for 'standards' dataset

APPENDIX 5 - FIG. 1

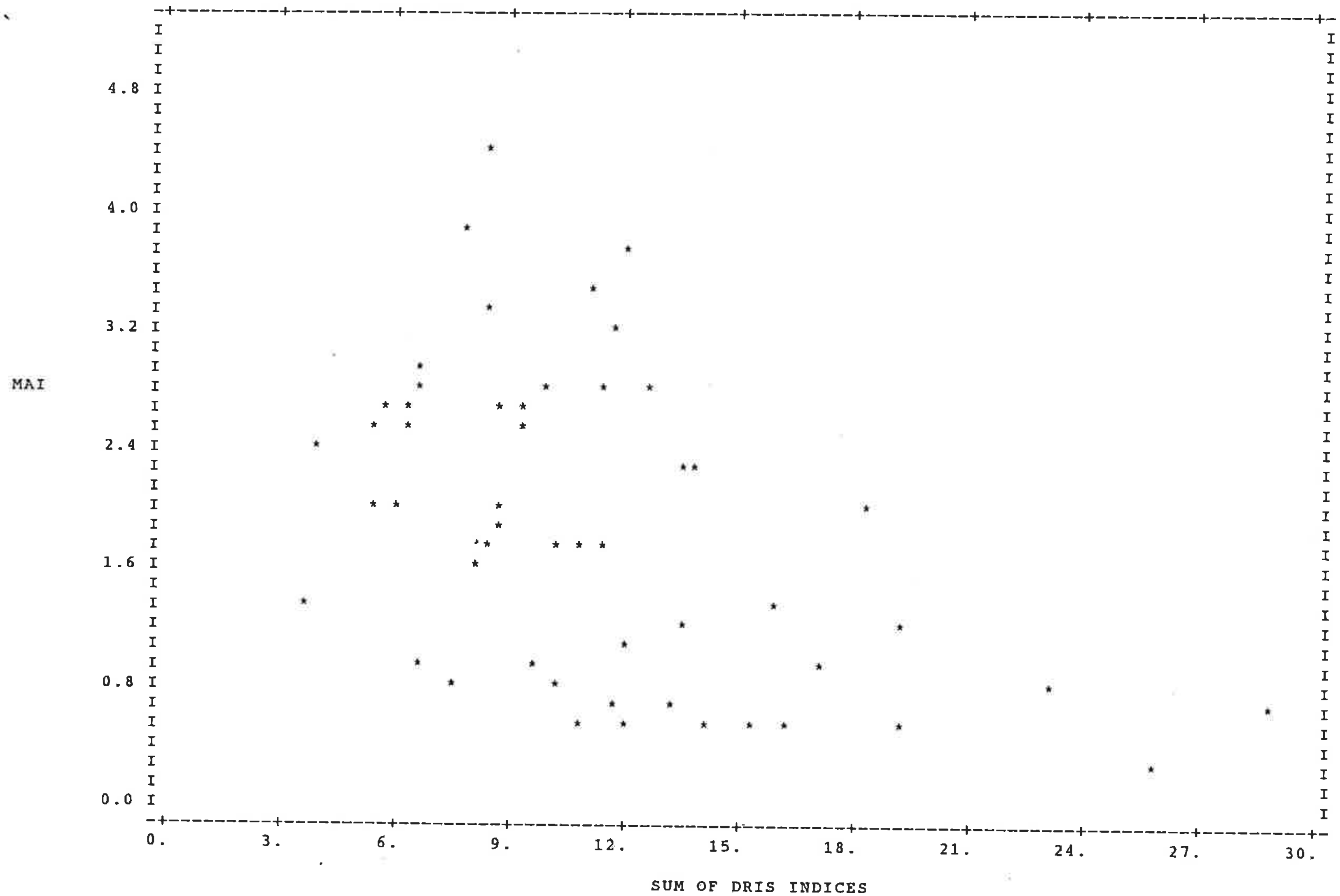

FIGURE 1 - Scatterplot of estimated mean annual increment (MAI) on absolute sum of DRIS indices for the <u>E.regnans</u> 'standards' dataset

APPENDIX 5 - FIG.2

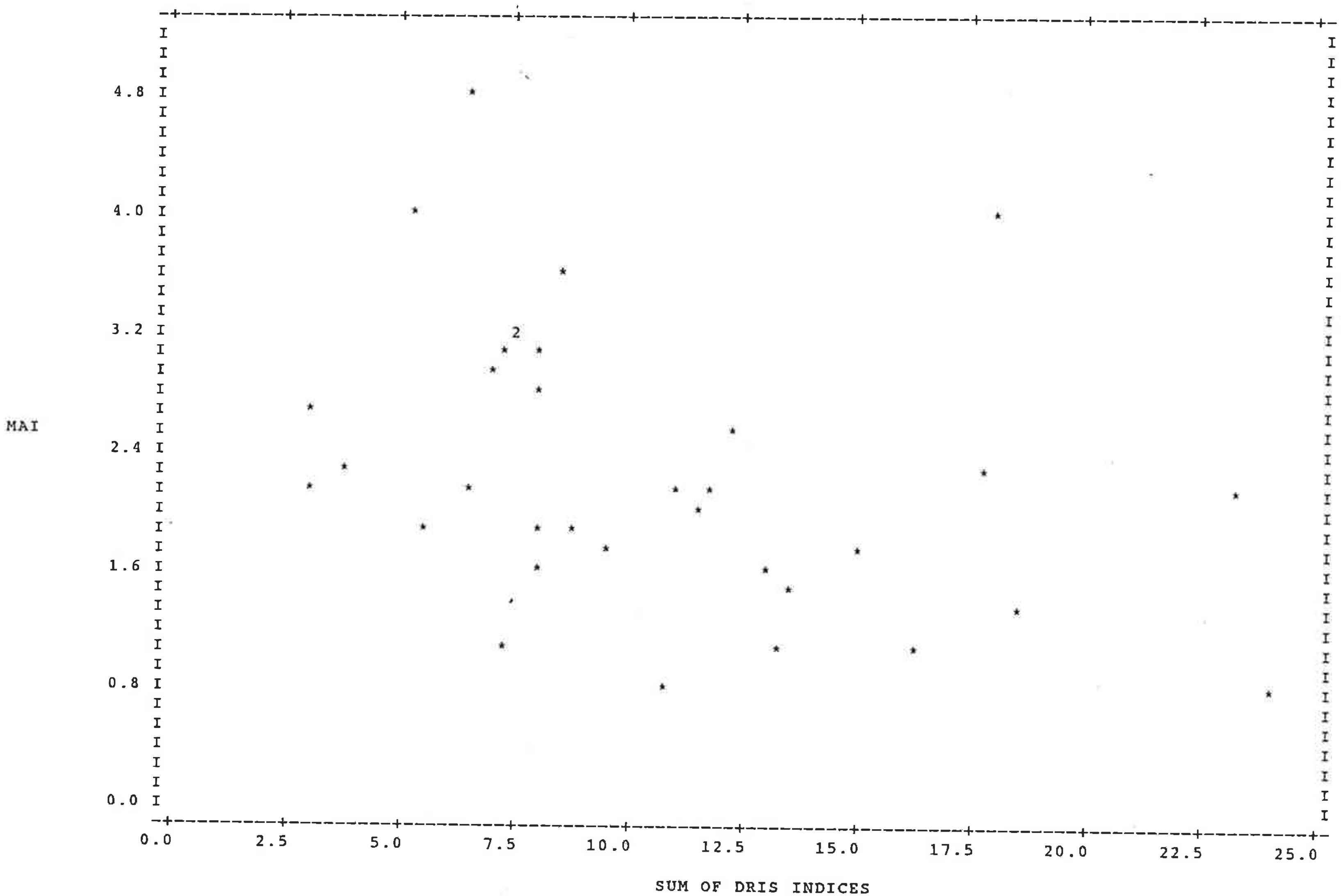

FIGURE 2 - Scatterplot of estimated mean annual increment (MAI) on absolute sum of DRIS indices for the <u>E. saligna</u> 'standards' dataset

APPENDIX 5 - FIG.3

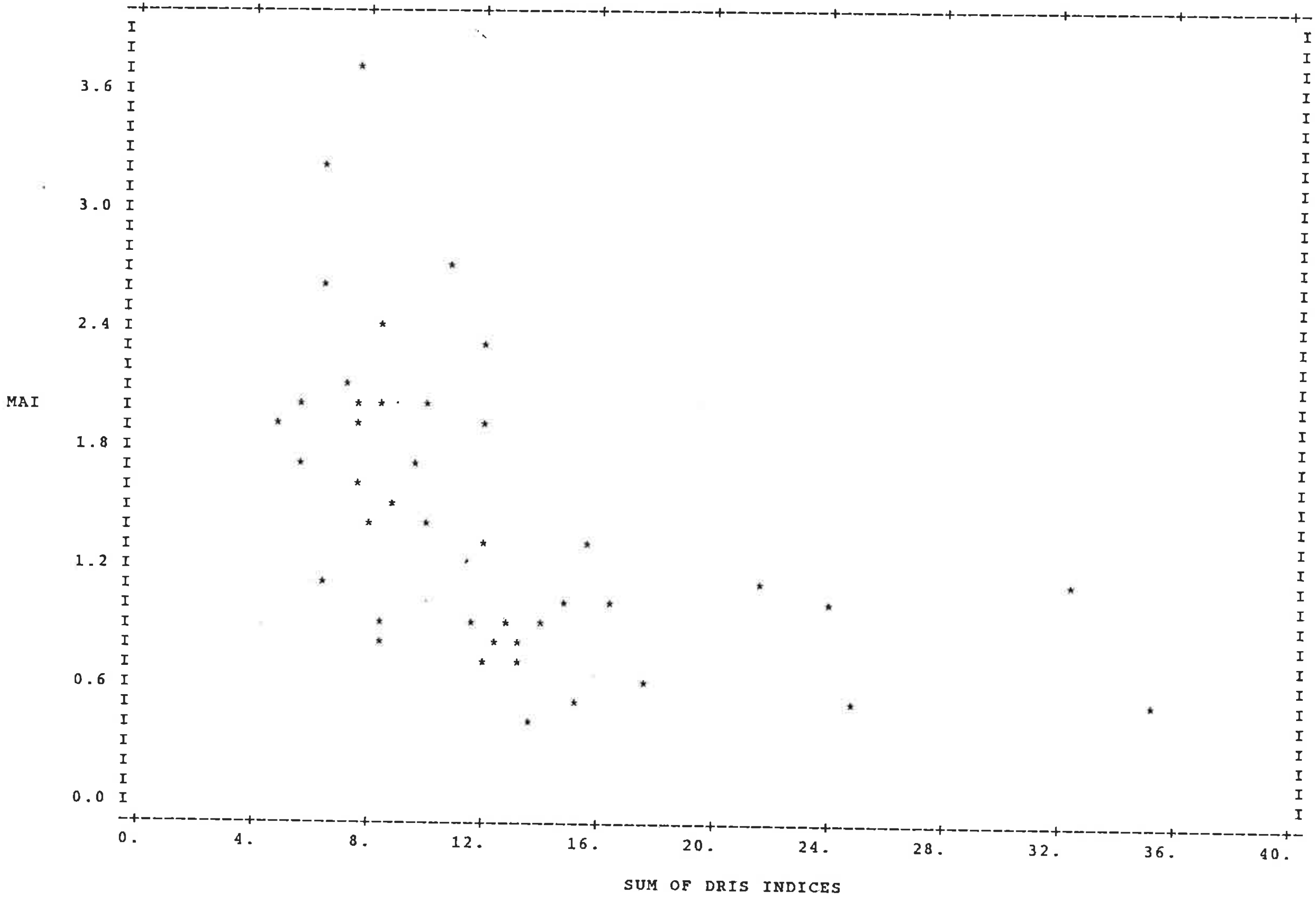

FIGURE 3 - Scatterplot of estimated mean annual increment (MAI) on absolute sum of DRIS indices for the <u>E. delegatensis</u> 'standards' dataset

APPENDIX TABLE 6 - Growth and [1]foliar concentration data from fertiliser trial AK1023-2 used to tes provisional DRIS standards for (A) *E. regnans* and (B) *E. saligna* (General means for the two species are compared in (C))

(A) *E. REGNANS*

[2]Trt	[3]Mean ht (cm)	[4]Mean ht incr. (cm)	N	P	K	Ca	Mg	B	Cu	Mn	Zn	N/I
			------------% oven dry wt ------------					----------ppm oven dry wt --------				
All	353a	121a	1.94	0.092	0.818	0.458	0.287	18.0a	4.4bc	494b	14.7	21.
NP	402a	137a	1.77	0.076	0.665	0.459	0.286	15.7b	3.3c	666a	12.7	23.
Nil	119b	16b	1.62	0.066	0.617	0.494	0.321	15.7b	6.1ab	68a	15.3	28.
All-N	178b	45b	1.75	0.088	0.795	0.480	0.294	13.3c	4.2c	381b	15.3	20.
All-P	127b	18b	1.85	0.067	0.721	0.522	0.298	16.3ab	7.1a	770a	19.3	28.
All-NP	122b	18b	-	-	-	-	-	-	-	-	-	-

(B) *E. SALIGNA*

[2]Trt	[3]Mean ht (cm)	[4]Mean ht incr. (cm)	N	P	K	Ca	Mg	B	Cu	Mn	Zn	N/P
			------------% oven dry wt ------------					----------ppm oven dry wt --------				
All	263a	69a	2.05	0.112a	0.920a	0.955	0.376	31.7ab	8.3	599 b	19.7	18.3
NP	288a	73a	1.92	0.107a	0.857a	0.876	0.386	26.0b	7.2	610 b	17.0	18.0
Nil	78b	15b	1.82	0.064bc	0.603bc	1.129	0.422	39.7a	9.9	1393 a	19.5	29.8
All-N	93b	26b	1.78	0.085ab	0.675b	1.148	0.458	36.3a	8.8	845 b	20.2	21.0
All-P	64b	11b	1.68	0.044c	0.485c	1.143	0.431	37.7a	9.3	1103 ab	-	39.5
All-NP	64b	10b	-	-	-	-	-	-	-	-	-	-

Note: Values in the same column followed by the same letter do not differ significantly at the 5% level (LSD test); where no lettering is shown the values in a column do not differ significantly

- = no data

APPENDIX TABLE 6 - (Cont'd) ...

(C) COMPARISON OF GENERAL MEANS FOR THE TWO SPECIES

[2]Trt+	[3]Mean ht (cm)	[4]Mean ht incr. (cm)	N	P	K	Ca	Mg	B	Cu	Mn	Zn	N/P
			-------------% oven dry wt					----------ppm oven dry wt				
E. regnans	217a	59	1.78	0.078	0.723	0.482b	0.294b	15.8b	5.0b	599b	15.5b	24.4
E. saligna	142b	34	1.85	0.083	0.708	1.050a	0.415a	34.3a	8.7a	910a	22.9a	25.3

\+ highly significant species x treatment interaction was recorded in this trial

1 Foliage samples were collected in Feb 1988 when the plantings were 2.5 years old

2 Treatments
(1) All = N P K Ca Mg S + B, Cu, Zn
(2) NP = N P only
(3) Nil = No fertiliser applied
(4) All-N = As for (1) but no N applied
(5) All-P = As for (1) but no P applied

The rates per application were (kg/ha) N:219, P:22, K:180, Ca:219, Mg:51, S:38
(g/ha) B:475, Cu:178, Zn:777

The N P K, part of Ca and micronutrients were applied in readily soluble form.
Sulphur was applied in elemental form; Mg, together with the balance of Ca was applied as dolomite

Applications (broadcast) were made soon after planting in June 1985 and were repeated in the autumn of the following year

3 Based on heights measured in the winter prior to sampling

4 Winter 1986-1987 i.e. for second year after outplanting.

APPENDIX TABLE 7.1 - List of shortened formulae used to compute DRIS indices for *E. regnans* foliar data from fertiliser trial AK 1023-2 (as a test of the provisional *E. regnans* DRIS standards)

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(1) N-index = $$\frac{-f((N/P) + f(N/K) + fN/Ca) + f(N/Mg) + f(N/B) + f(N/Mn) + f(N/Zn)}{7}$$

(2) P-index $$\frac{-f(N/P) + f(P/Mg)}{2}$$

(3) K-index = $$\frac{-f(N/K) + f(K/Ca) + f(K/Mg) + f(K/B) + f(K/Mn)}{5}$$
†

(4) Ca-index = $$\frac{-f(N/Ca) - f(K/Ca)}{2}$$

(5) Mg-index = $$\frac{-f(N/Mg) - f(P/Mg) - f(K/Mg)}{3}$$
†

(6) B-index = $$\frac{-f(N/B) - f\ (K/B)}{2}$$
†

(7) Cu-index = $$\frac{-f(Cu/Mn) + f(Cu/Zn)}{2}$$
†

(8) Mn-index = $$\frac{-f(N/Mn) - f(K/Mn) - f(Cu/Mn)}{3}$$
†

(9) Zn-index = $$\frac{-f(N/Zn) - f(Cu/Zn)}{2}$$
†

---

† As the test data lacked S, Fe,Al, Na and Cl values the 'full' formulae given in Appendix Table 3.2 were shortened as necessary to exclude any nutrient ratios involving these nutrients

APPENDIX TABLE 7.2 - List of shortened formulae[1] used to compute DRIS indices for *E. saligna* foliar data from fertiliser trial AK 1032-3 (as a test of the provisional *E. saligna* DRIS standards)

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(1) N-index = f(N / Ca)

(2) P-index = $\frac{f(P / Mg) + f(P / B)}{2}$

(3) K-index = $\frac{f(K / Ca) + f(K / Mg) + f(K / Cu) + f(K / Zn)}{4}$

†

(4) Ca-index = $\frac{-f(N / Ca) - f(K / Ca)}{2}$

(5) Mg-index = $\frac{-f(P / Mg) - f(K / Mg)}{2}$

(6) B-index = -f(P / B)

(7) Cu-index = -f(K / Cu)

(8) Zn-index = -f(K / Zn)

---

† As the test data lacked S, Fe, Al, Na and Cl values the 'full' formulae given in Appendix Table 3.2 wer shortened as necessary to exclude any nutrient ratios involving these nutrients

APPENDIX TABLE 8 - Application of DRIS to test data from fertiliser trial AK1023-2; (A) *E. regnans* and (B) *E. saligna*

Trt	[1]Mean ht incr. (cm)	Sum of DRIS indices	N	P	K	Ca	Mg	B	Cu	Mn	Zn
			[2] DRIS index								
(A) *E. REGNANS*											
All	121	5.34	0.30	-1.37	0.42	-0.02	0.51	-0.63	0.66	-0.10	-1.35
NP	137	6.33	0.29	-1.92	-0.07	0.40	1.16	-0.49	0.20	0.41	-1.39
Nil	16	8.23	-0.11	-2.48	-0.38	0.76	1.77	-0.19	1.15	0.33	-1.06
All-N	45	6.44	0.06	-1.47	0.60	0.28	0.94	-1.45	0.63	-0.26	-0.74
All-P	18	6.68	-0.02	-2.41	-0.02	0.50	1.21	-0.65	0.99	0.30	-0.58
(B) *E. SALIGNA*											
All	69	5.90	-1.05	-1.39	-0.38	0.82	1.45	0.59	0.09	-	0.13
NP	73	5.60	-1.01	-1.30	-0.31	0.77	1.76	0.11	0.00	-	-0.35
Nil	15	21.77	-1.95	-4.07	-2.30	2.12	3.73	3.27	1.81	-	2.52
All-N	26	16.82	-2.02	-2.89	-1.86	2.01	3.19	1.85	1.19	-	1.81
All-P	11	27.00	-2.16	-5.28	-2.84	2.51	4.83	4.27	2.11	-	3.01

1 1986-87 i.e. for second year after outplanting

2 Calculated using shortened DRIS index equations shown in Appendix Tables 7.1 and 7.2

\- Signifies no index

APPENDIX 9 - Scatterplots of yield index (CAI) on absolute sum of DRIS indices for test data from nutrient subtractive trial AK 1032-2

APPENDIX 9 - Fig. 4

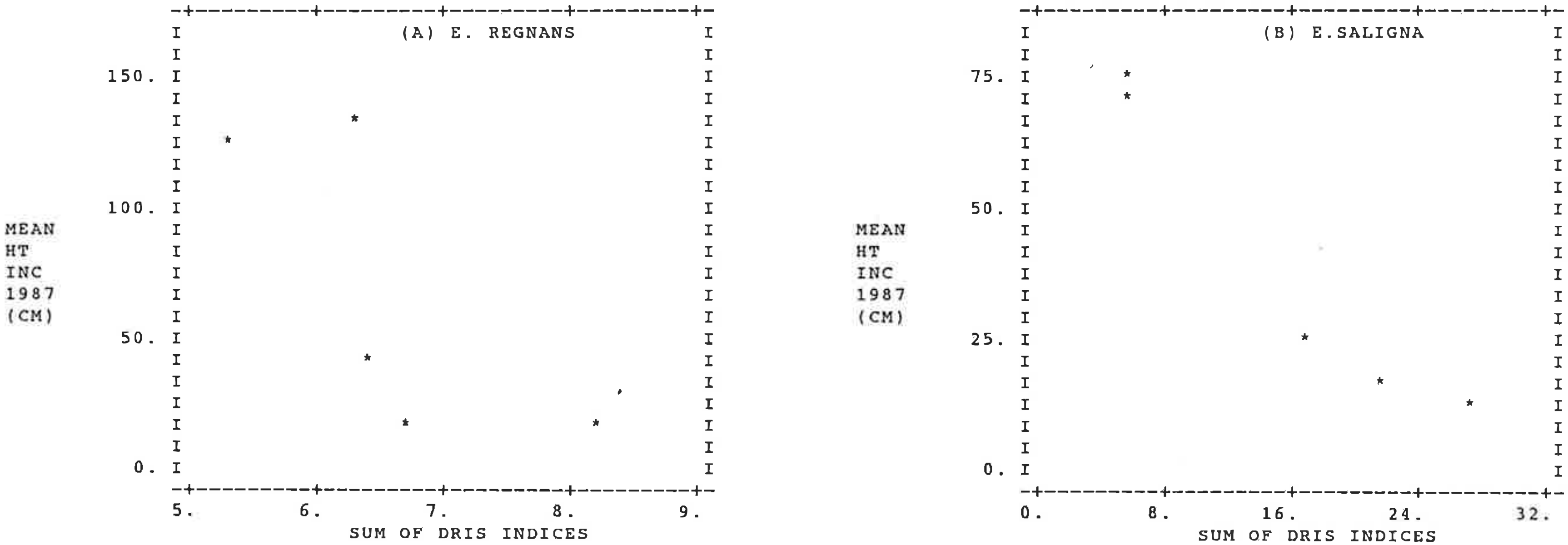

FIG. 4 - Scatterplots of mean height increment 1987 on absolute sum of DRIS indices for AK1023-2 test data : (A) *E. regnans*, (B) *E. saligna*

APPENDIX 10 - RESULTS OF STUDY COMPARING CONCENTRATIONS OF N, P, K, CA AND MG IN SAMPLES OF EUCALYPT FOLIAGE WITH AND WITHOUT LEAFSTALK REMOVED

SUMMARY

Samples of *E. regnans* leaves with petioles (leaf stalks) detached had comparable concentrations of N, K, Ca and Mg to those in samples of whole leaves, but significantly ($p \leq 0.01$) higher P concentrations (1.052 times the concentration in whole leaves).

Samples of *E. saligna* leaves with petioles detached had comparable concentrations of N, P, Ca and Mg to those in samples of whole leaves, but significantly ($p \leq 0.05$) lower concentrations of K (0.966 times the concentration in whole leaves).

The provisional DRIS standards were based on samples with petiole detached. If applied to data for samples of whole leaves of *E. regnans*, concentration values for P in oven dry weight should be adjusted upwards by a factor of 1.052 similarly for *E. saligna*, K concentrations in whole leaves should be adjusted downwards by a factor of 0.966.

INTRODUCTION

Leaf analysis usually involves the whole leaf blade, but the possibility of a gain in diagnostic sensitivity has led to investigation of separate portions of leaves as alternative standard sample tissues, such as leaf blade, petiole, or leaf blade less midrib (Cabral, 1963, Leaf, 1973, Martin Prevel *et al.* 1987).

Leonard and Wheeler (unpublished) reported that the contribution of the petiole to total leaf dry weight was 2.8-3.4% for *E. regnans* and that analyses showed that the concentration of macronutrients in the sample would be negligibly affected by exclusion of petiole material. They noted that for both *E. regnans* and *E. delegatensis* the petiole contains under one half of the amount of nitrogen but over twice the amount of calcium found in the blade.

In this study, the concentrations of N, P, K, Ca, and Mg in a series of paired samples of eucalypt foliage with and without the leaf stalk attached respectively were compared for two eucalypt species (*E. regnans* and *E. saligna*).

The original intention was for the samples to be analysed for the full range of nutrients/elements determined in the DRIS survey (see Work Plan 1750). However foliar data for S, Al, Na, Cl or the micronutrients B. Cu, Fe, Mn and Zn are not available for the paired samples.

METHODS

Two species were studied, *E. regnans* and *E. saligna*. Samples of fully expanded leaves produced in the current season were collected from young trees (stand age 2-3) of each species from the upper third of crown. For each species twenty separate samples were collected from twenty different trees.

Each sample was well mixed and divided into two subsamples. Of these, one subsample was left intact, while the other had all petioles detached at the point of insertion into the base of the leaf blade. The resultant samples were logged in pairs as either '+' and '-' petiole' respectively.

The individual samples were oven-dried, and later analysed in the same batch by the preparation and ('wet' chemistry) analysis methods described by Nicholson (1984).

The resultant foliar data for each species were subjected to a paired t-test.

RESULTS

The results of the study are summarised in the following table:

E. REGNANS

Treatment	N	P	K	Ca	Mg
	----------	----------	% oven dry wt	----------	----------
+ petiole	1.852	0.249	0.632	1.082	0.211
- petiole	1.831	0.262	0.638	1.097	0.234
SED	0.043	0.003	0.014	0.027	0.016
Paired t statistic	0.47	4.38	0.37	0.54	1.44
Significance	NS	**	NS	NS	NS

E. SALIGNA

Treatment	N	P	K	Ca	Mg
	----------	----------	% oven dry wt	----------	----------
+ petiole	1.987	0.097	0.746	0.912	0.215
- petiole	1,984	0.099	0.721	0.922	0.221
SED	0.019	0.002	0.012	0.018	0.004
Paired t statistic	0.10	1.20	2.09	0.60	1.73
Significance	NS	NS	*	NS	NS

Note:
* = significant at the 5% level
** = significant at the 1% level
NS = not significant at the 5% level
SED = standard error of difference of mean

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APPENDIX 11 - Glossary of terms used relating to DRIS

SAMPLE FOR DRIS: a survey-based selection of samples used as the DRIS dataset to represent the total NZ population.

DRIS : Diagnostic Recommendation and Integrated System - A mathematical means of ordering a large number of nutrient expressions (e.g. ratios and/or products) into nutrient indices (q.v) that can be more easily interpreted.

'DESIRABLE' GROUP : High-yielding segment (subgroup) of the sample.

'UNDESIRABLE' GROUP : Low-yielding segment (subgroup) of the sample.

CUT-OFF VALUE (for high- and low-yielding subgroups) : In our study we used the general mean of MAI (mean annual increment) values for the population sample. The actual cut-off value used is not critical provided the high-yielding sub-group remains normally distributed.

YIELD : In our study we used an approximation to MAI (mean annual increment), calculated as mean tree height/stage age, as an index of productivity or yield.

'IMPORTANT' NUTRIENT RATIOS : These are nutrient ratios shortlisted as contributing in an important way to high yield. Their selection was made on the basis of (1) a significantly larger variance in the low-yielding segment than in the high-yielding subgroup (provided the mean value was greater in the latter subgroup), or a significantly greater mean value for the high-yielding segment than that for the 'low' subgroup (even where variance values were not necessarily significantly different).

NUTRIENT EXPRESSIONS : The form in which individual nutrient pairs are used in the DRIS index equations, e.g. for N and P the possibilities are N/P, P/N or N*P.

DRIS NUTRIENT INDEX : An equation in which the index for a particular nutrient is expressed as the mean of all 'functions' of nutrient ratios (or products) containing that nutrient. Indices which have positive values indicate relative sufficiency or excess, whereas those having a negative value signify relative deficiency; conversely the larger a positive value the greater the relative excess. Values of zero or close to zero indicate an optimal relative balance.

FUNCTIONS : Each 'function' of nutrient ratio (or product) used in DRIS index equations consists of a comparison of the ratio (or product) found in an individual plant sample with the DRIS norm (q.v.) for that ratio. The magnitude of the resultant deviation is scaled by dividing the deviation by the coefficient of variation (CV) of the ratio for the high-yielding subgroup. In the simplified version of the function (proposed by Beverly (1987) natural logarithm transformed data are used and the CV is replaced by standard deviation:

$$f(A/B) = (Ln\ (A/B) - Ln\ (a/b))\ /\ SD$$

where

A/B	is the ratio in the plant sample
a/b	is the norm for the ratio
Ln	is the natural log
SD	is the standard deviation of the log transformed norm for a/b.

ABSOLUTE SUM OF DRIS INDICES : This is the sum of all DRIS indices for a particular sample when the signs are disregarded. The sum affords some measure of the total nutritional balance in a plant. A value of zero, or close to it signifies a sound balance; large values indicate serious nutritional imbalance. If a low sum is obtained for a sample from a 'low-yielding' plant, this may indicate that an unmeasured factor rather than nutrition *per se.* is limiting growth.

DRIS STANDARDS : These are the DRIS norms and corresponding standard deviations of the norms.

DRIS NORMS : The norm for an 'important' ratio (or product) is the mean of all the values of that ratio (or product) in the dataset for the high-yielding subgroup.

ADDENDUM TO PROJECT RECORD NO. 2185

ADDITIONAL TESTING OF DRIS PROVISIONAL STANDARDS BY APPLICATION TO GLASSHOUSE NUTRITION TRIAL DATA

P.J. KNIGHT and S.O. HONG

SUMMARY

Additional testing of provisional DRIS standards was conducted by application to foliar data from a closely regulated glasshouse nutritional trial with eucalypt seedlings. The results show that

1. DRIS indices generally correctly identified individual nutrients whose supply was deliberately restricted or withheld.

2. Absolute sum of DRIS indices for samples did not always provide a reliable indication of overall nutritional balance.

The shortcomings of the provisional standards may arise from the narrowness of the database used to generate the standards. Revising the standards on the basis of a suitably expanded database should help to improve the diagnostic accuracy of the system.

INTRODUCTION

Only very limited testing of the provisional DRIS standards has to date been possible because of a lack of suitable field experimental data relating to 2/3-year-old eucalypt stands.

In view of the need to broaden testing of the standards it was decided, subsequent to preparation of the main report, to make use of data from an earlier glasshouse nutrition trial (Knight, unpublished).

Application of the provisional standards to data pertaining to container-grown 6-month-old seedlings may be invalid, as the standards were derived for foliage samples from 2-3 year forest stands. However, applying the provisional standards to the data from the carefully regulated glasshouse trial affords an opportunity of testing whether the computed indices correctly identify nutrients which were either withheld singly or kept in low supply (relative to all other nutrients).

METHODS

The methods used in the glasshouse trial from which the test data were drawn are described in Production Forestry Division (PFD) Project Record No. 522, (Knight, unpublished). The effects which nutrient supply had on foliar concentrations and dry matter production in this trial are described in PFD Project Record Nos 1046, 1044 and 1072 (Knight, unpublished).

The computations of DRIS indices were made using Genstat 5 (Lawes Agricultural Trust, 1990).

The provisional DRIS standards which were used are those presented in the revised version of Project Record 2185 (Knight, Hong and Allen, unpublished). DRIS formulae used to compute the DRIS indices for foliar data from the glasshouse trial were modified to include as many selected nutrient ratios as the range of analyses would allow:

MACRONUTRIENT SERIES:

E. regnans

As the range of nutrients determined in the macronutrient series was confined to macronutrients (N, P, K, Ca, Mg, S) only six indices could be calculated; these were based on 8 selected ratios: N/P. N/K, N/Ca, N/Mg, N/S, P/Mg, K/Ca and K/Mg.

E. saligna

The number of ratios selected for *E. saligna* in the initial studies was smaller than for *E. regnans*; this meant that only five indices could be calculated. and these were based on only four ratios: N/Ca, P/Mg, K/Ca and K/Mg. Thus the result of additional tests for this species must be considered as tentative only.

MICRONUTRIENT SERIES

Twelve nutrients were determined in foliage from the micronutrient trial series. This meant that, for *E. regnans*, 23 selected ratios were available to calculate 11 DRIS indices; for *E. saligna* 8 selected ratios were available to calculate 9 DRIS indices. The two indices which were calculated for *E. regnans*, but not for *E. saligna*, were those for S and Mn.

RESULTS

The foliar and yield data drawn from a glasshouse nutrition trial (Knight, unpublished) and used for additional testing of provisional DRIS standards (Knight, unpublished) are presented in Tables 1 and 2 (macronutrient supply levels varied), and Table 3 (supply of individual micronutrients omitted or modified by heavy liming[1]. The data presented in Tables 1 and 3 relate to standard foliage samples, while those in Table 2 relate to total foliage samples.

1. APPLICATION OF DRIS TO STANDARD FOLIAGE SAMPLES FROM GLASSHOUSE TRIAL

1.1 Macronutrient treatment series

E. regnans:
DRIS indices

The DRIS indices computed from the foliar data for *E. regnans* given in Table 1 are presented in Table 4.

The indices for the control treatment (A_5 = all nutrients at the 'full' supply level 5) show that relatively, the most limiting nutrient was nitrogen. This conclusion seems quite plausible.

The indices for the other five treatments for which standard foliar data are available, correctly identify the most limiting nutrient in each treatment:

---

1 (10% w/w $CaCO_3$ incorporated with substrate).

Treatment		Most limiting nutrient
N_2	all nutrients at supply level 5 except N (= supply level 2)	N
K_1	all nutrients at supply level 3 except K (= supply level 1)	K
Ca_O	all nutrients at supply level 5 except Ca (= omitted from supply)	Ca
Mg_1	all nutrients at supply level 5 except Mg (= supply level 1)	Mg
S_1	all nutrients at supply level 5 except S (= supply level 1)	S

Absolute sum of DRIS indices

Treatments A_5 and S_1, with the highest dry matter yields, appropriately have the lowest absolute sums of indices signifying they are suffering the least overall nutritional imbalance. For the treatments overall however, the relationship between sum and dry matter production (Fig. 1) is weak, with the value for Mg_1 in particular an outlier. For this treatment (Mg_1) the sum of indices is unexpectedly low in relation to dry matter yield.

E. saligna

DRIS indices

The DRIS indices computed from the foliar data for *E. saligna* given in Table 1 are presented in Table 4.

The indices which are computed from a very limited range of selected ratios (see Methods) and therefore of questionable reliability, suggest that productivity of the control (A_5) treatment was most limited by P supply and then by N supply.

The indices for five of the six treatments examined correctly identify the nutrient most limiting in each treatment. For the sixth treatment (S_1), no S index could be calculated and the results are therefore inconclusive.

Absolute sum of DRIS indices

As for *E. regnans*, the sums for the A_5 and S_1 treatments for treatments in *E. saligna* are the lowest indicating least overall nutritional imbalance; overall the relationship between sum and dry matter production, is rather weak (Fig. 1), mainly because of the outlier value for S_1; this treatment has an unexpectedly low sum in relation to its yield. This aberration can perhaps be explained by the fact that, for reasons explained above (see Methods), the sum excludes any contribution from an S index: for the S_1treatment (see *E. regnans* data in Table 4) an S-index could be expected to be relatively large..

1.2 Micronutrients treatment series

The DRIS indices calculated for the micronutrient trial series are presented for both species in Table 5.

The only micronutrient which, when omitted from nutrients applied, caused a statistically significant reduction in dry matter production (DMP) relative to control, and overt symptoms of deficiency, was boron. The liming treatment caused a significant reduction in DMP for *E. regnans*, but not for *E. saligna*.

The DRIS indices for both species accurately indicate a serious relative deficiency of boron in the B_0 treatment.

For *E. regnans* the DRIS indices correctly indicate Mn as relatively the most limiting nutrient in the Mn_0 treatment and Zn in the Zn_0 treatment. In the lime treatment (A_5L) the indices indicate Mn as being relatively the most limiting and calcium the relatively most oversupplied element. The Cu_0 treatment is indicated as only very slightly deficient in Cu, but, as neither significant dry weight depression nor symptoms of deficiency were recorded in the plants of this treatment, the seedlings were evidently able to meet their requirement of Cu from that in the seed and present as an impurity in the substrate and/or applied chemicals.

For *E. saligna* the DRIS indices did not reflect any serious relative deficiencies in Cu, Fe or Zn. As neither symptoms nor significant growth depression was recorded for these treatments, it appears that, despite depressed foliar concentrations of Cu and Fe in seedlings of the Cu_0, and Fe_0 treatments respectively, the seedlings obtained sufficient of these elements from seed reserves and from impurities in the substrate or supply, to adequately meet their metabolic requirements.

As for *E. regnans*, the Ca-index for the *E. saligna* seedlings in the liming treatment indicated a serious relative oversupply of Ca; no Mn index could be calculated for this species.

The sum of DRIS indices for the B_0 treatment for *E. regnans* is appropriately the highest value for this series, but is not large enough to indicate serious imbalance in seedlings despite the evidence of depressed dry matter production.

In the micronutrient series for *E. saligna* the lime treatment has the highest absolute sum of DRIS indices value followed by Mn_0 and, close behind, the B_0 treatment; control appropriately has the lowest sum (i.e. best overall balance) of the treatments.

2. TOTAL FOLIAGE SAMPLES FROM MACRONUTRIENT TREATMENT SERIES

Table 6 lists DRIS indices for total foliage samples from the *E. regnans* and *E. saligna* seedlings calculated using the foliar data presented in table 3: These data for the macronutrient treatments are included here because sufficient standard foliage was sometimes lacking for analysis where treatments seriously depressed seedling growth. The data are useful to show how reducing supply of an element changed the value of the index for that element (Table 7):

The relationship between the absolute sums of DRIS indices and seedling dry matter productivity is generally weak in this series (Fig. 2); the sums do not generally appear to provide a dependable indication of overall nutritional balance.

CONCLUSIONS

Further testing of provisional DRIS standards by application to foliar and yield data from a closely regulated glasshouse nutritional trial with eucalypt seedlings gave mixed results. On the one hand, DRIS indices computed using the provisional standards generally correctly identified individual nutrients whose supply was deliberately restricted or with held; on the other hand, absolute sum of DRIS indices was not always a reliable indicator of overall nutritional balance.

The test results indicate that the DRIS system has good prospects for application to eucalypts, but that further refinement of standards is needed to develop a system with reliable diagnostic capability. Refinement calls for an expansion of the database used to derive DRIS standards for each species and examination of alternative nutrient expressions such as products and inverse ratios of nutrient pairs.

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Table 1. Glasshouse trial data (Knight, unpublished) used for further testing of provisional DRIS standards for eucalypts: the standard foliar data are for a range of **macronutrient treatments**.

(A) E. REGNANS

Trt	Dry wt (g)	N	P	K	Ca	Mg	S
		% dry wt					
A5	17.6	1.19	0.111	0.60	0.39	0.212	0.120
N2	6.8	1.04	0.136	0.80	0.44	0.224	0.115
K1	15.6	1.24	0.107	0.22	0.40	0.230	0.103
Ca0	10.3	1.51	0.128	0.74	0.04	0.296	0.130
Mg1	15.8	1.27	0.106	0.80	0.41	0.049	0.120
S1	17.2	1.38	0.122	0.60	0.41	0.207	0.083

(B) E. SALIGNA

Trt	Dry wt (g)	N	P	K	Ca	Mg	S
		% dry wt					
A5	17.7	1.11	0.089	0.52	0.39	0.212	0.102
N2	7.6	0.98	0.144	0.95	0.54	0.243	0.098
K1	15.2	1.14	0.106	0.24	0.44	0.235	0.103
K0	8.6	1.84	0.151	0.24	0.65	0.311	0.143
Ca0	9.0	1.39	0.100	0.84	0.04	0.278	0.127
Mg1	8.7	1.58	0.112	0.78	0.51	0.063	0.120
S1	16.0	1.38	0.108	0.62	0.51	0.295	0.083

NOTE: The control treatment is represented by symbol A5 (= full dose of all nutrients).

The dosage (nil, one-fifth , or two-fifths of the full dose) and the nutrient varied in other treatments are indicated by the nutrient chemical symbol and a numeral 0, 1 or 2 respectively; in these treatments , with the exception of A1, all other nutrients were supplied at the full dosage (level 5); in A1 all nutrients were supplied at one-fifth of the full rate.

Table 2. Glasshouse trial data (Knight unpublished) used for additional testing of provisional DRIS standards for eucalypts; the foliar data are for **standard foliage samples** from the **micronutrient treatment** series.

(A) E. REGNANS

Trt	Dry wt	N	P	K	Ca	Mg	S	B	Cu	Fe	Mn	Zn	Na
	(g)	% dry wt						ppm dry wt					%
A5	17.6	1.19	0.111	0.60	0.39	0.212	0.120	18.0	3.2	38	169	13.8	0.29
−B	10.5	1.58	0.174	1.09	0.29	0.212	0.130	6.0	3.5	54	185	14.5	0.33
−Cu	12.4	1.48	0.133	0.66	0.35	0.212	0.130	19.0	2.5	48	177	16.0	0.26
−Fe	17.5	1.18	0.112	0.55	0.37	0.203	0.125	16.5	3.0	54	142	12.0	0.36
−Mn	15.9	1.28	0.118	0.55	0.50	0.253	0.125	19.5	3.0	40	47	13.5	0.39
−Zn	17.1	1.11	0.103	0.52	0.36	0.199	0.115	16.0	2.5	63	145	9.0	0.29
A5+L	9.9	1.72	0.110	0.80	1.28	0.205	0.140	21.5	6.0	80	92	24.0	0.29

(B) E. SALIGNA

Trt	Dry wt	N	P	K	Ca	Mg	S	B	Cu	Fe	Mn	Zn	Na
	(g)	% dry wt						ppm dry wt					%
A5	17.7	1.11	0.089	0.52	0.39	0.212	0.102	15.0	4.4	69	197	15.8	0.45
−B	8.1	1.15	0.104	0.69	0.32	0.135	0.090	13.0	5.0	55	152	17.0	0.25
−Cu	19.7	1.14	0.094	0.48	0.40	0.179	0.100	16.5	1.5	78	160	14.0	0.51
−Fe	17.1	1.13	0.092	0.52	0.46	0.251	0.095	15.5	3.0	53	191	20.5	0.48
−Mn	14.3	1.33	0.112	0.64	0.46	0.244	0.120	19.5	7.0	119	62	34.5	0.45
−Zn	15.5	1.21	0.106	0.62	0.42	0.242	0.105	18.5	4.0	48	188	22.5	0.51
A5+L	17.4	1.38	0.084	0.44	1.52	0.172	0.120	15.0	5.5	52	78	46.0	0.40

NOTE: The control treatment is represented by symbol A5 (= full dose of all nutrients).

The dosage (nil, one-fifth , or two-fifths of the full dose) and the nutrient varied in other treatments are indicated by the nutrient chemical symbol and a numeral 0, 1 or 2 respectively; in these treatments , with the exception of A1, all other nutrients were supplied at the full dosage (level 5); in A1 all nutrients were supplied at one-fifth of the full rate.

Table 3. Glasshouse trial data (Knight unpublished) used for additional testing of provisional DRIS standards for eucalypts; the foliar data are for total foliage samples from the macronutrient treatment series.

(A) E. REGNANS

Trt	Dry wt/pot (g)	N	P	K	Ca	Mg	S
		% dry wt					
A5	35.2	1.11	0.09	0.54	0.46	0.24	0.12
N2	13.6	0.97	0.12	0.69	0.44	0.21	0.11
N1	4.5	0.96	0.19	0.82	0.49	0.25	0.10
P2	7.1	2.08	0.07	0.83	0.40	0.21	0.15
P1	1.5	2.32	0.06	0.92	0.43	0.23	0.15
K1	31.2	1.15	0.09	0.19	0.44	0.25	0.10
K0	8.8	2.80	0.23	0.25	0.78	0.47	0.19
Ca0	20.7	1.41	0.11	0.64	0.07	0.30	0.13
Mg1	31.5	1.18	0.09	0.46	0.13	0.15	0.09
S1	34.4	1.27	0.10	0.56	0.53	0.23	0.08
S0	3.8	2.31	0.26	0.98	0.78	0.35	0.09
A5+L	19.8	1.73	0.11	0.84	1.59	0.22	0.14
A1	1.5	2.23	0.09	0.76	0.41	0.23	0.14

(B) E. SALIGNA

Trt	Dry wt/pot (g)	N	P	K	Ca	Mg	S
		% dry wt					
A5	35.5	1.17	0.09	0.50	0.39	0.23	0.10
N2	15.2	0.97	0.14	0.85	0.54	0.24	0.10
N1	3.2	1.10	0.16	1.02	0.63	0.30	0.10
P2	5.1	1.72	0.07	1.00	0.37	0.20	0.16
P1	2.7	1.31	0.08	0.66	0.30	0.18	0.15
K1	30.5	1.29	0.10	0.24	0.52	0.28	0.11
K0	17.3	2.02	0.17	0.24	0.81	0.41	0.16
Ca0	18.1	1.57	0.11	0.79	0.06	0.29	0.14
Mg1	17.4	2.26	0.13	0.79	0.49	0.07	0.14
S1	32.0	1.36	0.11	0.64	0.55	0.29	0.10
A5+L	34.7	1.28	0.08	0.45	2.04	0.20	0.12
A1	1.5	1.66	0.08	0.77	0.45	0.23	0.11

NOTE: The control treatment is represented by symbol A5 (= full dose of all nutrients). The dosage (nil, one-fifth , or two-fifths of the full dose) and the nutrient varied in other treatments are indicated by the nutrient chemical symbol and a numeral 0, 1 or 2 respectively; in these treatments , with the exception of A1, all other nutrients were supplied at the full dosage (level 5); in A1 all nutrients were supplied at one-fifth of the full rate.

Table 4. DRIS indices and total sums of indices for **standard** eucalypt foliage samples from the **macronutrient treatment** series in a glasshouse nutrition trial (Knight, unpublished).

(B) E. SALIGNA

Trt	Dwt (g)	N	P	K	Ca	Mg	S	Sum of DRIS indices
		DRIS index						
A5	17.6	-1.4230	0.3957	0.383	0.592	0.493	2.511	5.80
N2	6.8	-2.3709	1.1982	1.195	0.753	0.392	3.195	9.10
K1	15.6	-0.3750	0.1085	-2.527	1.757	1.551	1.074	7.39
CaO	10.3	0.2286	-0.0132	2.158	-5.757	0.861	1.339	10.56
Mg1	15.8	-0.3498	1.9164	2.302	0.297	-3.871	2.029	10.77
S1	17.2	-0.3436	0.4408	0.194	0.514	0.182	-1.319	2.99

(B) E. SALIGNA

Trt	Dwt (g)	N	P	K	Ca	Mg	S	Sum of DRIS indices
		DRIS index						
A5	17.7	-0.234	-0.879	-0.193	-0.037	0.787	-	2.12
N2	7.6	-1.573	0.421	0.985	0.246	-0.655	-	3.88
K1	15.2	-0.514	-0.608	-2.927	1.350	2.139	-	7.54
K0	8.6	-0.251	-0.331	-3.947	1.762	2.476	-	8.77
Ca0	9.0	7.208	-1.462	4.006	-7.603	0.724	-	21.00
Mg1	8.7	0.018	4.567	2.747	-0.354	-4.685	-	12.37
S1	16.0	-0.385	-1.396	-0.584	0.167	1.307	-	3.84

NOTE: The control treatment is represented by symbol A5 (= full dose of all nutrients).
The dosage (nil, one-fifth , or two-fifths of the full dose) and the nutrient varied in other treatments are indicated by the nutrient chemical symbol and a numeral 0, 1 or 2 respectively; in these treatments , with the exception of A1, all other nutrients were supplied at the full dosage (level 5); in A1 all nutrients were supplied at one-fifth of the full rate.

Table 5. DRIS indices and absolute sums of indices for **standard** eucalypt foliage samples from **micronutrient subtractive treatments** in a glasshouse nutrition trial (Knight, unpublished).

(A) E. REGNANS

Trt	Dwt (g)	N	P	K	Ca	Mg	S	B	Cu	Fe	Mn	Zn	Sum of indices
		DRIS Index											
ALL	17.6	-0.9859	0.3957	0.4382	0.592	0.4930	1.477	0.624	0.7813	-1.1633	-0.669	0.280	7.90
-B	10.5	-0.0054	1.2483	0.2608	-1.241	-0.6970	1.906	-4.537	0.6011	-0.3661	-0.857	-0.637	12.36
-Cu	12.4	-0.4960	0.5469	0.4759	-0.094	0.0187	0.951	0.348	-0.1582	-0.6335	-0.707	0.634	5.06
-Fe	17.5	-0.9847	0.4914	0.3633	0.571	0.4478	1.913	0.367	0.5395	0.2187	-0.885	-1.262	8.04
-Mn	15.9	-0.7553	0.2334	0.3953	1.222	0.9273	1.837	0.881	0.9802	-0.7787	-1.912	-0.166	10.09
-Zn	17.1	-0.9260	0.3721	0.3379	0.650	0.5769	2.182	0.500	0.3106	1.2487	-0.823	-3.022	10.95
+lime	9.9	-0.8496	-0.2698	0.2291	2.766	-0.2538	-0.445	0.298	1.1185	0.2225	-1.673	1.761	9.89

(B) E. SALIGNA

Trt	Dwt (g)	N	P	K	Ca	Mg	S	B	Cu	Fe	Mn	Zn	Sum of indices
		DRIS Index											
ALL	17.7	-0.2345	0.1186	-0.4502	-0.0366	0.7867	-	-1.117	-0.0848	0.887	-	0.893	4.61
-B	8.1	0.4592	1.7522	1.0345	-1.0538	-1.6052	-	-2.093	0.3073	-1.036	-	-0.381	9.72
-Cu	19.7	-0.2305	0.4746	-0.0478	0.1084	0.2129	-	-0.984	2.4344	1.652	-	0.645	6.79
-Fe	17.1	-0.6724	-0.1368	-0.5808	0.4126	1.3294	-	-1.118	0.8838	-0.109	-	2.476	7.72
-Mn	14.3	-0.1877	0.2340	-1.4625	-0.1193	0.5044	-	-1.011	-0.7339	2.160	-	4.378	10.79
-Zn	15.5	-0.1983	0.1417	-0.0360	-0.1966	0.6327	-	-1.003	0.6011	-1.146	-	1.973	5.93
+lime	17.4	-3.6330	0.3096	-2.8861	3.7929	0.4299	-	-0.928	-1.0716	0.450	-	8.405	21.91

Note: - signifies no data ; see notes to foregoing tables for key to treatments

Table 6. DRIS indices and total sums of indices for **total foliage samples** from a range of **macronutrient treatments** in a glasshouse nutrition trial with eucalypts (Knight, unpublished).

(A) E. REGNANS

Trt	Dwt (g)	N	P	K	Ca	Mg	S	Sum of indices
		------------DRIS index					------------	
A5	35.2	-1.6597	-0.2684	-0.060	1.229	1.1768	3.027	7.42
N2	13.6	-2.3554	1.0222	0.920	1.020	0.5170	3.382	9.22
N1	4.5	-2.8931	2.2348	1.179	1.108	0.4966	2.752	10.66
P2	7.1	0.6682	-2.0317	0.626	-0.491	-0.0666	0.026	3.91
P1	1.5	1.0613	-2.8150	0.652	-0.577	0.1014	-0.783	5.99
K1	31.2	-0.5240	-0.3833	-2.990	2.272	2.1327	1.413	9.72
K0	8.8	0.5848	0.0793	-4.229	2.177	1.8920	-0.425	9.39
Ca0	20.7	-0.1622	-0.3668	1.394	-4.075	1.2218	1.847	9.07
Mg1	31.5	0.1500	0.1905	0.795	-1.877	-0.0678	0.441	3.52
S1	34.4	-0.6528	-0.1425	-0.187	1.360	0.7894	-0.977	4.11
S0	3.8	0.0614	1.1672	0.019	0.867	0.0348	-4.538	6.69
A5L	19.8	-1.1297	-0.3664	-0.230	3.252	-0.1046	0.880	5.96
A1	1.5	0.8592	-1.5019	0.206	-0.423	-0.0212	-1.002	4.01

(B) E. SALIGNA

Trt	Dwt (g)	N	P	K	Ca	Mg	S	Sum of indices
		------------DRIS index					------------	
A5	35.5	-0.078	-1.145	-0.453	-0.060	1.124	-	2.86
N2	15.2	-1.603	0.362	0.662	0.416	-0.458	-	3.50
N1	3.2	-1.688	0.024	0.632	0.419	-0.219	-	2.98
P2	5.1	1.225	-1.566	2.001	-1.752	-0.079	-	6.62
P1	2.7	1.039	-0.664	1.188	-1.372	-0.003	-	4.27
K1	30.5	-0.643	-1.490	-3.458	1.647	2.877	-	10.12
K0	17.3	-0.628	-0.926	-4.723	2.258	3.243	-	11.78
Ca0	18.1	6.364	-1.262	3.179	-6.530	0.800	-	18.14
Mg1	17.4	1.201	4.732	2.663	-1.019	-4.610	-	14.23
S1	32.0	-0.653	-1.262	-0.562	0.362	1.157	-	4.00
A5L	34.7	-4.732	-1.062	-2.849	4.721	1.024	-	14.39
A1	1.5	0.537	-1.589	0.683	-0.770	0.613	-	4.19

NOTE: The control treatment is represented by symbol A5 (= full dose of all nutrients). The dosage (nil, one-fifth , or two-fifths of the full dose) and the nutrient varied in other treatments are indicated by the nutrient chemical symbol and a numeral 0, 1 or 2 respectively; in these treatments , with the exception of A1, all other nutrients were supplied at the full dosage (level 5); in A1 all nutrients were supplied at one-fifth of the full rate.

TABLE 7 - DRIS indices arraigned by supply level for macronutrient treatments series: (A) *E. regnans*, and (b) *E. saligna*

(A) *E. regnans*

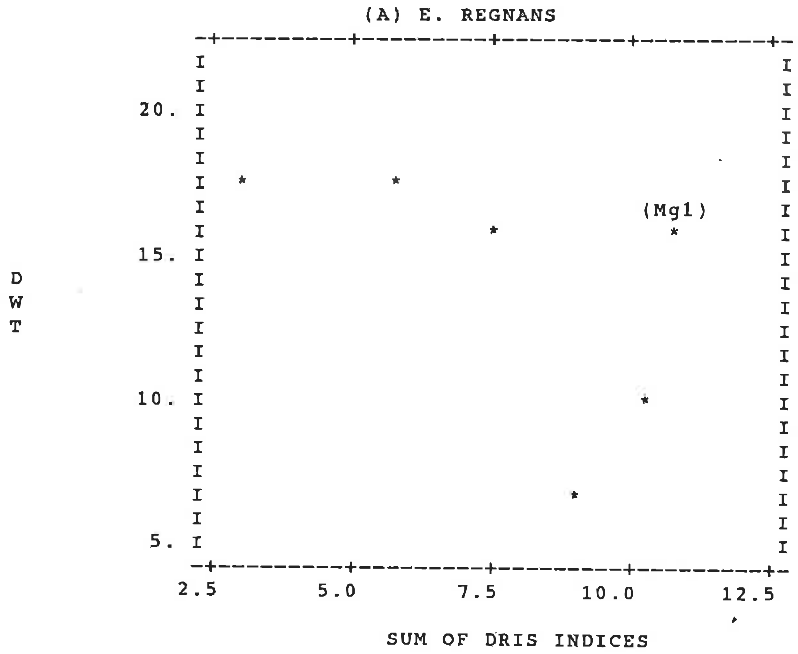
Element	Supply level 5	Supply level 2	Supply level 1	Supply level 0
	DRIS index			
N	-1.66	-2.36	-2.89	-
P	-0.27	-2.03	-2.82	-
K	-0.06	-	-2.99	-4.23
Ca	1.23	-	-	-4.08
Mg	1.18	-	0.07	-
S	3.03	-	-0.98	-4.54

(B) *E. saligna*

Element	Supply level 5	Supply level 2	Supply level 1	Supply level 0
	DRIS index			
N	-0.08	-1.60	-1.69	-
P	-1.14	-1.57	-0.66	-
K	-0.45	-3.46	-	-4.72
Ca	-0.06	-	-	-6.53
Mg	1.12	-	-4.61	-
S	-	-	-	-

- no data

Figure 1. Scatterplots of dry matter yield per pot on absolute sum of DRIS for macronutrient treatments represented by standard foliage samples: (A) **E. regnans** and (B) **E.saligna**.



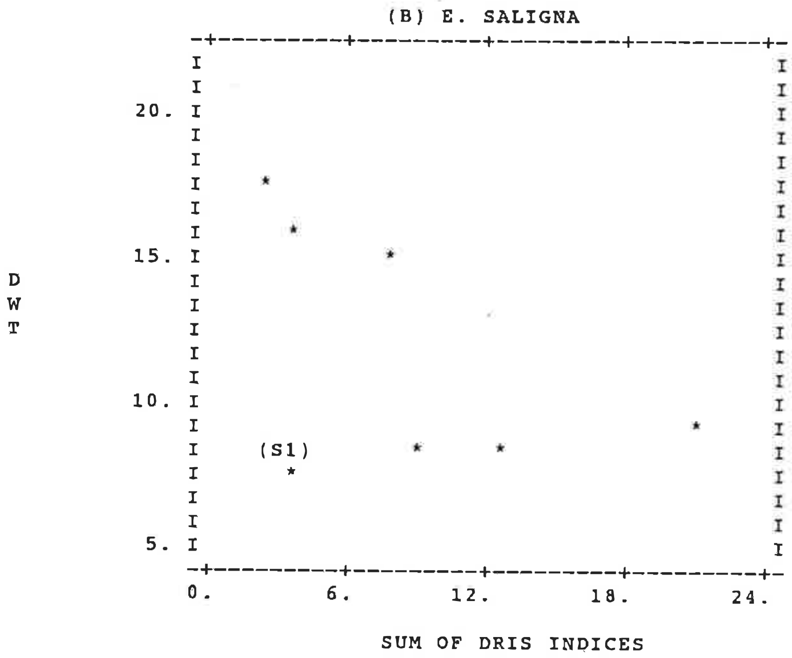


Figure 2. Scatterplots of dry matter yield per pot on absolute sum of DRIS indices for macronutrient treatments represented by total foliage samples: (A) *E. regnans* and (B) *E. saligna*