HNS 57
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HNS 57

LITERATURE REVIEW OF CRITICAL NUTRIENT THRESHOLDS AND WIDER ASPECTS OF NURSERY STOCK NUTRITION

Project Duration: 1.1.95 to 30.9.95

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PROJECT OUTLINE

Contract No: HNS57

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1 TITLE OF PROJECT

Literature Review of Critical Nutrient Thresholds and Wider Aspects of Nursery Stock Nutrition.

2 BACKGROUND AND COMMERCIAL OBJECTIVE

Plant analysis is widely used commercially for the determination of nutrient levels and has for many years provided a more complete guide to the adequacies and inadequacies of fruit fertiliser programmes. It would therefore seem vital to have the same information available for HNS production. It is not possible to apply this technology directly as a tool to determine nutrient levels in HNS production because of the large range of species, growing conditions and the lack of detailed knowledge of critical nutrient thresholds. That the technique can be useful is demonstrated in the protected crops, field vegetable and fruit sectors.

Sampling techniques are also important. For a plantation of strawberries, for example, a sample of about 25 new, fully expanded leaves would be taken just before harvest. The sample specification has to be this detailed for the results to be relevant to previously set standards of nutrient content. A similar specification would have to be ascertained for each HNS species.

The main purchases of hardy nursery stock (HNS) increasingly set a more exacting standard, requiring growers to produce plants which are of a consistently high standard and grown to tight schedules. This requires increased awareness of plant nutritional status throughout the year. Increasingly this will create demand for more precision in nutrient application.

A wider knowledge of critical nutrient levels within the plant will provide a clearer understanding of the type of nutrient management necessary for a particular purpose eg

Propagation: Nutrient levels in mother stock prior to cutting harvest. The effect of deficiencies on both scion and stock in grafting techniques.

Vegetative Growth: Optimising extension growth in ornamental species. Maximising vegetative growth in heavily irrigated cell/liner plants.

Winter Hardiness: The degree of winter hardiness conferred by nutrient management.

Longevity and Shelf Life: The effect of nursery nutrition - practice on the shelf life of container grown plants.

Knowledge in these areas will create a valuable management tool for the future once the critical nutrient thresholds have been determined.

3 POTENTIAL FINANCIAL BENEFIT TO THE INDUSTRY

Losses to the UK HNS industry from poor nutritional practice could be as high as 15% and leads to a reduction of the growers competitive edge and profitability. The value of HNS in 1993 was assessed at £244 million of which £127.5 million is container-grown stock. Estimate of loss could therefore be as high as £36.6 million and this proposal seeks to significantly reduce this.

The review will provide the base from which to proceed. It will identify areas where improvements to growing techniques and possible savings, both in time and money, can be made.

4 SCIENTIFIC/TECHNICAL TARGET OF THE WORK

To provide a written review of current knowledge on optimum nutritional levels in HNS on the basis of the following outline;

Section A (SUMMARY).

Section B (INTRODUCTION) to provide from the literature search and personal communications, details of the limiting factors to growth which have been identified as being due to the result of nutrient disbalance or deficiency.

Section C (CURRENT KNOWLEDGE) is the main core of the review, offering detail of work to date, determining the range of nutrient levels over which most plants thrive and identifying thresholds. Where possible, tables will be collated for a range of species and, where available, cultivars. Attention will be drawn to areas where knowledge is deficient. The review will seek to identify sources and scope of information from a wide range of research centres.

Section D (CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE WORK) is intended to state specifically which areas are most suitable for HDC and government funding.

5 CLOSELY RELATED WORK - COMPLETED OR IN PROGRESS

Nutrient threshold levels for HNS are not known for production in the UK but some work has been completed as back-up to other nutritional studies.

Plants analysis as the most easily accessed and cheapest technology is used in the USA, although their results are not strictly relevant to UK conditions, may well provide useful guidelines.

Northern Europe research data will be assessed from the literature search.

Data available from HRI Efford and HRI East Malling as part of previous nutritional work will prove most useful.

There are no known projects funded by MAFF or other bodies with which this project can be integrated.

6 DESCRIPTION OF THE WORK

1 Literature search - search mechanism to interrogate databases such as:

(i) Databases on compact disc (a) CAB Abstract 1984 onwards
(b) AGRICOLA 1970 onwards.

(ii) On-line searching - worldwide - DIALOG 1972 onwards.

2 Personal communication with those responsible for MAFF, SOAFD and DANI funded projects, including HRI East Malling/HRI Efford.

A compilation of plant analysis data from HRI stations.

Manufacturers of nutrient products eg Phosyn, Atlas Interlates, BASF.

3 Review unpublished work eg by A Blain *et al* of SAC.

4 Consideration of closely related work at other UK and European research centres.

Signed for the Contractor(s)

Signature..

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Date.....24 January 1995

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Position..

Date..

Signed for the Council

Signature..

Position....CHIEF EXECUTIVE

Date.....17.1.95

CHAPTER 1

SUMMARY

The information available on the nutrient requirements of hardy nursery stock (HNS) is generally product orientated with little work being carried out on defining exactly the nutritional requirements of either particular species or genera.

Although many factors other than nutrition influence the growth of plants it has been shown that the use of substrate and tissue analysis together provide the best means of assessing growth potential. Guideline levels for tissue analysis have been compiled. The case for the use of liquid feeding late on into the autumn and the plants ability to take up nitrogen while dormant has been made before in Whalley's review but still remains an under utilised tool. Nutrition of container grown plants and the effects of high phosphate on susceptible species is well documented; this work highlights the need for more research into the complex arena of nutritional balance at various stages of plant production by the diverse methods now used. In the absence of extensive research the use of mycorrhiza is discussed and methods of application given. A list of topics for research and development from which the industry could benefit is suggested although it is expected that many other topics could appear on a 'wish-list'.

CHAPTER 2

INTRODUCTION

"Compared with other woody perennial crops, relatively little detailed information is available on the levels of fertiliser application and requirements for optimum growth and development of nursery stock. With the growing importance of these crops for amenity planting in both the public and private sectors more work is required in this field. The role of the essential elements, the levels of nutrients within the plant and their function, the interactions between nutrients, the relation of the stage of plant development to nutrition, the transport of nutrients within the plant, the determination of the nutrient status by leaf analysis and soil-plant relationships are all matters on which more information is needed".

D N Whalley, ADAS Quarterly Review 1974.

The purpose of this literature review is to determine the present state of knowledge with regard to the nutrition of hardy nursery stock (HNS) twenty years on from Whalley's review.

During this time the industry has developed into a highly competitive, quality sensitive, efficient business. The use of controlled release fertilisers (CRF), non-peat based composts and detailed specifications for all stages of plant material have become the norm yet the nutrition of most HNS remains a mystery. The level of control exercised on nurseries is often limited to the amount of CRF incorporated into the substrate and whether calcium carbonate is required. This is not a reflection of the industry's ability but of the world-wide deficiency of knowledge.

A comparison can be made between HNS and the tomato industry where many years have been spent researching and developing the nutrition of this one crop yet the use of liquid feeding for HNS is rare and like the use of CRF's the type and ratio chosen is usually on the basis of availability rather than being species specific.

Critical nutrient thresholds can be defined as the level of nutrients available to the plant at which it is either receiving a shortfall or excess of nutrients. Within this often narrow band the plant will generally flourish if the nutrients are available to the plant and are balanced.

Almost all the research and development work which has been and is being carried out in northern Europe and north America is concerned with food crops or heated glasshouse plants. The relevance of nutritional recommendations for particular genera will be examined with reference to HNS production which may have very different requirements or specifications.

The main purchasers of HNS increasingly set more exacting standards, requiring growers to produce plants which are of a consistently high standard and grown to tight schedules. This requires an increased awareness of plant nutritional status throughout the year and will create the demand for more precision in the application of nutrients.

The main objective of this review is to ascertain, where possible, the critical levels of nutrition by means of tissue analysis and other means for HNS but also to suggest areas of research and development work which should be funded by either central government or HDC.

CHAPTER 3

BASIS FOR HNS NUTRITION PRACTICE

Modern HNS production using plastic pots and soil-less media dates to about the mid 1960's. Substrates became standardised based on the University of California mixes for various purposes ie seed, potting etc. This situation did not last very long but ensured a more consistent method of approach to plant nutrition.

The advent of slow-release fertilisers provided a means of extending the nutritional life of the mix but was quickly overtaken by coated fertilisers with a controlled-release characteristic (Osmocote, Ficote or Plantacote). Fertilisers that are temperature dependent for their nutrient release rather than moisture level.

During this period of change a number of researchers around the world concentrated their efforts on determining threshold levels for HNS plants being grown in containers and in the field.

The uptake of nutrients, specifically and in general is of major importance. Scott-Russell (1970) reviewed this subject and outlined relevant radioactive tracer techniques, however as certain crops show a requirement for ammonium nitrogen and others iron deficiency due to high phosphate levels (Scott 1982) or a higher requirement for specific trace elements the preference for a standard fertiliser for all species was favoured. Growers were content to vary the mix for calcifuge species by omitting calcium carbonate but not to have various mixes for different species.

The products being used were nearly always controlled-release fertilisers. The ratio of macro nutrients and life of the products were unusual compared to previous practice.

The reasoning behind the ratio of Osmocote is based partly on Dutch advisory work which arrived at recommendations based on soil samples (personal communication Scotts Europe BV).

Table 3.1 Nutritional Status of Potting Mix for Container Grown Plants (Defined within the 1-1.5 method) in mmol/l

Group A = Low Feeders,
Group B = Normal to Heavy Feeders

EVALUATION	NH4 + Group A	NO3 Group B	P	K	Mg	Ca	SO4
Low	< 1.1	< 2.1	< 0.11	< 0.5	< 0.4	< 0.4	< 0.4
Average	1.1 - 2	2.1 - 3	0.20	0.8	0.5	0.9	0.8
Good	2.1 - 3	3.1 - 4	0.45	1.3	0.8	1.5	1.2
High	3.1 - 4	4.6 - 6	0.75	1.8	1.1	2.2	1.7
To High	> 4.5	> 6.0	> 0.9	> 2.0	> 1.2	> 2.5	>2.0

Based on these values a NPK balance of 6-1-3 would be ideal if the growing media is inert and the growing conditions are not influenced by variabilities like rain, light, temperature, growing season etc. Since this is not the case, other factors need to be taken into consideration.

1 Part of the nitrogen will be leached out, especially with normal NPK granular and water soluble fertilisers. So for controlled release fertilisers the N figure can be lower.

2 P might be buffered by the soil, so the figure could be a bit higher.

3 Both P and K are required during different times of the growing season. After potting more P for rooting is required. In the autumn it is necessary to have more K for hardening off the plants.

4 Dependence on existing raw material suppliers.

Therefore, the bulk of Osmocote Plus products, recommended for normal container nursery stock, have an NPK balance of 6-3-4. Of course there are speciality products for those species known to require differing nutrition.

The range of CRF's has varied over the years as has the longetivity and ratios available. The recent adjustments to the iron content of Osmocote Plus as a result of on-going trials suggests that about 30% of plant species grown in northern Europe demand a higher level of iron than had been supplied in order to produce quality plants. This adjustment indicates a refining of nutritional practice but still a very general approach.

Work at Efford (Scott 1982) investigated chlorotic symptoms on container-grown plants indicated iron deficiency and showed a complex inter-relationship and great diversity in sensitivity by species to phosphate. Reducing the available phosphate levels in compost improved the quality of plants, high levels depressed growth and under high pH regimes the effects became toxic (Table 3.67).

This work also highlighted various species as being sensitive to high levels of nutrition and new recommendations using various rates of CRF for different species became accepted. Even with these more definitive recommendations growers are still adding to and making up their own recipes with only empirical evidence to support the practice.

Experimental work from north America during the 1970's and 80's touched on some interesting aspects of nursery stock nutrition and at times verged on determining critical nutrient thresholds. Work in Canada, Hicklenton at Agricultural Research Station, Kentville, Nova Scotia, using Cotoneaster and Juniper found that by liquid feeding the increase of the relative growth rate (RGR) during one month tended to have a negative influence on RGR during subsequent months. This would suggest that although plants on the highest levels of nitrogen achieved the highest total seasonal relative dry weight gain the growth rate was far from consistent.

Work in Yugoslavia (Komlenovic *et al* 1986) was able to demonstrate that leaf analysis of Picea abies, P. omorika and P. sitchensis were closely correlated with the dry matter content of two year old seedlings. Tree height was also variable depending upon nutrition and 81% of the variation was explained by nitrogen, phosphorus, potassium, magnesium and calcium concentrations in the leaves. Responses to fertiliser were exhibited without deficiency symptoms being evident.

These two examples demonstrate the marked influence correct nutrition can exert on producing quality plants both in containers and in the field. Furthermore the relationship between leaf nutrient concentrations and plant growth provide a useful means of assessing critical nutrient thresholds.

Research in New Zealand (Cresswell, 1989) on vines and top fruit in China (Li *et al* 1988) suggest a significant correlation between the contents of soil N vs leaf N, soil K vs leaf K, soil Fe vs leaf Fe and soil Mn vs leaf Mn. In the light of the results obtained changes to the fertiliser programme with the aim of establishing a better nutrient balance and improvements in fruit quality are expected. Guidance for rational fertilisation should depend neither on soil or leaf analysis alone but on the interpretation and integration of both.

One of the largest surveys of leaf analysis on HNS species carried out was conducted between 1968 and 1974 from plants in nurseries throughout Ohio (Smith 1978). Seven hundred and twenty four foliar analysis samples representing 150 different species and cutivars of woody ornamentals were assessed and found to be quite similar between deciduous and evergreen species as noted in Table 3 full details of analysis data are shown in Appendix I.

In all instances, Ca, Mg and B were somewhat higher in deciduous foliage and Zn was slightly lower.

The significance of the similarity of mineral element values between deciduous and evergreen plants will be the simplification of diagnosing mineral element imbalance and making future fertiliser recommendations based on foliar analysis.

In as much as all plants in the survey and most plants from the industry samples were healthy and growing satisfactorily, it can be assumed that the values presented in Tables 3.21, 3.22 and 3.23 can be interpreted as sufficient for growth of a wide range of woody ornamentals. Further research remains to more critically define lower (deficient), optimum and upper (excess) mineral element levels for woody ornamentals.

Table 3.21 Average Foliar Mineral Element Values of 107 Deciduous and Evergreen Species and Cultivars of Woody Ornamentals from a Survey of Commercial Nurseries

Plant Type	Number of Plants	N	P	K	Ca	Mg	Mn	Fe	B	Cu	Mo	Zn	Al
		percent					ppm						
Deciduous	80	2.40	0.33	1.23	1.54	0.36	113	224	31	13	2.2	33	332
Evergreen	27	2.11	0.31	1.19	0.96	0.23	187	213	27	15	1.9	54	314

Table 3.22 Average Foliar Mineral Element Values of 617 Samples Representing 85 Deciduous and Evergreen Species and Cultivars of Woody Ornamentals from Grower Samples Submitted for Analysis

Plant Type	Number of Samples	N	P	K	Ca	Mg	Mn	Fe	B	Cu	Mo	Zn	Al
		percent					ppm						
Deciduous	76	2.19	0.34	1.59	1.12	0.31	147	219	40	9	2.0	47	236
Evergreen	541	2.17	0.39	1.58	0.72	0.28	238	189	27	10	1.4	53	168

Table 3.23 Average Foliar Mineral Values of 724 Samples of Deciduous and Evergreen Species and Cultivars of Woody Ornamentals from a Nursery Survey and Grower Samples Submitted for Analysis

Plant Type	Number of Samples	N	P	K	Ca	Mg	Mn	Fe	B	Cu	Mo	Zn	Al
		percent					ppm						
Deciduous	156	2.30	0.34	1.41	1.33	0.34	130	222	36	11	2.1	40	284
Evergreen	568	2.14	0.35	1.38	0.84	0.26	213	201	27	13	1.7	54	241
Average	724	2.22	0.35	1.40	1.09	0.30	172	212	32	12	1.9	47	263

(Smith, 1978)

Work by Richardson (1988) has put together data from the USA, GCRI, Australia, Holland, Efford and the Forestry Commission to give a broad view of both high and low levels, many examples of deciduous and evergreen plants are shown.

This paper also raises the problem of determining whether other factors such as incorrect pH, restricted uptake because of disease, high salts, waterlogging or simple substrate nutrient imbalance could be the cause of an apparent deficiency or toxicity.

The Dutch work referred to by Richardson is from Aendekerk (1982). This provides some useful guidelines but the plants were grown under glass usually in rockwool with the specific nutrient deficiency induced. This does not define the critical levels but only the levels of the nutrient in the foliage when added (+) or omitted (-) from the solution (Appendix II).

The Colour Atlas of Nutritional Disorders (Bergmann 1992) provides some very useful colour photographs and also tables giving the range of nutrients from foliar analysis for adequate levels to be determined (Appendix III).

Reuter and Robinson (1987) in Plant Analysis - an interpretation manual, have re-drawn a table presented by Bunt (1976), Table 3.4, which averages leaf tissue analysis of ornamental plants.

Table 3.3 Average Micro-element Ranges Found in Leaf Tissue of Hardy Ornamental Plants (ppm in dry matter)

ELEMENT	DEFICIENT	NORMAL	EXCESSIVE
Copper	< 5	10 - 25	> 70
Zinc	< 15	30 - 100	> 200
Manganese	< 20	30 - 200	> 1000
Boron	< 20	30 - 80	> 150
Molybdenum	< 0.1	0.1 - 3	> 70

Reuter and Robinson also produced tables from a literature search identifying deficient, marginal, adequate, high and toxic levels of nutrients for azalea subsequently this data was reviewed by Richardson (1988).

As might be expected the work of the Forestry Commission on coniferous species is very much better documented. Nutrient Deficiencies of Conifers in British Forests, Forestry Commission Leaflet 76 is an illustrated guide giving foliar analysis, deficiency levels compared to healthy and a table of the likelihood of nutrient deficiency by site types and early growth stages. This type of publication although concerned primarily with timber production does provide guidelines for HNS.

As a general guide and comparison with other examples Table 3.5 indicates the levels that could be expected in nursery planting stock. The values given are for current shoots in late autumn for conifers and for the foliage of broadleaved species in mid-summer.

Table 3.4 Marginal Range of Nutrient Concentrations in Forest Nursery Stock

	Major Nutrients					
	N	P	K	Ca	Mg	S
	(% Oven Dry Weight)					
Pines	1.5-1.8	0.16-0.18	0.6-0.7	0.06-0.10	0.07-0.10	0.15-0.20
Spruces	1.2-1.6	0.16-0.18	0.5-0.7	0.10-0.15	0.06-0.08	0.13-0.18
Larches	2.0-2.5	0.20-0.25	1.0-1.2	0.20-0.25	0.10-0.12	0.16-0.20
Other Conifers	1.6-1.8	0.18-0.20	0.7-0.8	0.15-0.20	0.10-0.12	0.16-0.18
Alder, Birch, Sycamore, Cherry, Lime, Willow, Norway Maple	2.3-2.8	0.18-0.25	1.0-1.2	0.15-0.20	0.10-0.15	0.14-0.20
Other Broadleaves	1.7-2.3	0.14-0.20	0.7-1.0	0.20-0.30	0.15-0.20	0.16-0.20
	Trace Elements					
	Cu	**Fe**	**Mn**	**B**		
	(µg/g)					
Pines and Spruces	3-5	20-40	20-40	15-30		
Other Conifers	3-5	40-60	40-60	20-40		
Broadleaves	3-5	30-80	30-80	20-40		

1 Below marginal levels indicative of deficient status.
2 Above marginal levels indicative of satisfactory status.
3 Conifers = current shoots in late autumn.
4 Broadleaves = foliage in midsummer. (Proe 1994)

Forestry Authority, Forest Nursery Practice Bulletin 111.

Table 3.5 Deficient and Optimum Foliar Nutrient Concentrations for Stands of 0.3-3.5 m Mean Height, as per cent Oven-dry Weight

	Mean Needle Weight Associated With Poor Growth	NITROGEN		PHOSPHORUS		POTASSIUM		MAGNESIUM	
SPECIES	Mg	Def	Opt	Def	Opt	Def	Opt	Def	Oft
Sitka Spruce Norway Spruce	(<3.5) (<1.5)	< 1.2	> 1.5	< 0.14	> 0.18	< 0.5	> 0.7	(< 0.03	> 0.07)
Lodgepole Pine Scots Pine	< 10.0	< 1.1	> 1.4	< 0.12	> 0.14	< 0.3	> 0.5	(< 0.03	> 0.05)
Corsican Pine	< 20.0	< 1.2	>1.5	< 0.12	> 0.16	(< 0.3	> 0.5)	(< 0.03	> 0.05)
Douglas Fir	(< 2.0)	(< 1.2	> 1.5)	(< 0.18	> 0.22)	(< 0.6	> 0.8)	(< 0.04	> 0.06)
Western Hemlock	(< 1.2)*	(< 1.2	> 1.5)	(< 0.25	> 0.30)	(< 0.6	> 0.8)	-	-
Japanese Larch Hybrid Larch	(< 3.0)	(< 1.8	> 2.5)	(< 0.18	> 0.25)	(< 0.5	> 0.8)	-	-

Notes: *Values in brackets are tentative. *This species has a very variable needle size.*

TISSUE ANALYSIS

Tissue analysis as a technique for determining the nutrient levels within the plant have been shown by many workers to be useful and reliable. Davidson (1960) and Bollard (1957) demonstrated that the nutrient composition within a genus of woody ornamentals was similar to the pattern established for fruit trees and that the seasonal nutrient trends were also similar to those reported for deciduous fruit crops. Further the nutrient composition did not vary greatly between species. This may be too general a comment for the intensive production of HNS species where considerable differences in growth have been demonstrated by varying the nutrient balance of the substrate and as a consequence the levels within the plant.

EFFORD WORK 1980-1994

The container-grown HNS trials at HRI Efford since 1979 have included as part of the assessment foliar analysis at various stages of growth. This has produced a large amount of tabulated data which requires further detailed evaluation. In an attempt to utilise the information and produce figures which can be used as guidelines for particular species means have been calculated, although this may not be strictly statistically correct it is outwith the realms of this review to embark on a more detailed evaluation of the information.

Table 3.6 shows the guideline levels which have been arrived at from observation and recordings.

Table 3.6

SPECIES	AVERAGE DRY WEIGHT (g)	% N	% P	% K	% Mg	% Ca	Mn mg/kg	Fe mg/kg	B mg/kg	Cu mg/kg	Zn mg/kg	Mo mg/kg
Juniperus communis 'Repanda'	16.2	2	0.2	0.7	0.3	-	-	-	-	-	-	-
Chamaecyparis lawsoniana 'Columnaris Glauca'	51	1.4	0.2	0.5	0.2	-	-	-	-	-	-	-
Chamaecyparis lawsoniana 'Stardust'	22.95	1.80	0.27	0.84	0.16	0.59	100	-	-	-	-	-
Chamaecyparis lawsoniana 'Allummii'	36.45	1.24	0.20	0.35	0.21	0.85	756	83	-	-	-	-
Chamaecyparis 'Ellwoods Gold'	21.25	1.30	0.35	0.61	0.21	0.78	1,092	96	-	-	-	-
Chamaecyparis pisifera 'Boulevard'	13	2.99	0.38	0.85	0.49	0.86	522.5	-	-	7.92	-	-
X Cupressocyparis leylandii	47	1.3	0.1	0.7	0.3	-	-	-	-	-	-	-
Mahonia japonica	26	1.5	0.1	0.7	0.2	-	-	-	-	-	-	-
Elaeagnus pungens 'Maculata'	9.5	2.8	0.4	2	0.2	-	-	-	-	-	-	-
Cytisus x praecox	30	2.6	0.2	0.6	0.2	-	-	-	-	-	-	-
Prunus laurocerasus	15	2.7	0.3	0.9	0.4	1.3	71.7	-	-	3.8	-	-
Viburnum burkwoodii	11.95	1.94	0.28	0.52	0.41	1.78	692.5	-	-	-	-	-
Camellia 'Kramers Supreme'	17.15	1.54	0.14	0.57	0.37	1.22	2797.5	98	-	-	-	-
Skimmia japonica 'Foremanii'	9.73	2.07	0.14	1.28	0.41	1.31	390	92	-	-	-	-
Erica carnea 'Springwood White'	4.1	1.87	0.21	0.51	0.27	0.45	378	141	-	-	-	-
Calluna vulgaris 'Sunset'	2.75	1.49	0.16	0.37	0.16	0.46	-	-	-	-	-	-
Hydrangea 'Mme J De Schmedt'	9.55	2.53	0.38	0.73	1.24	1.96	357	253.5	-	-	-	-
Magnolia soulangiana	14.4	1.75	0.09	1.81	0.42	1.35	881	105	-	-	-	-
Japanese Azalea 'Blue Danube'	13.2	2.02	0.20	0.61	0.38	1.59	356	-	-	-	-	-
Cotoneaster cornubia	33.05	1.58	0.22	0.89	0.40	1.45	85	-	-	-	-	-
Cotoneaster horizontalis	26.9	2.2	0.22	1.05	0.34	0.75	338	-	-	-	-	-
Hypericum calycinum	15.9	2.0	0.31	0.87	0.33	-	923	-	78	5.68	50	0.43
Berberis darwinii	11.76	1.61	0.16	0.62	0.16	-	502	-	40.8	4.51	39	0.59

For further detail and explanation of data see Appendix V.

CHAPTER 4

OPPORTUNITIES TO ADJUST NUTRITION

The modern practice of using CRF's does not offer many opportunities for varying the levels of nutrient either within the substrate or the plant unless commercial practice changes. The use of substrate and leaf analysis together have been shown by researchers both within the food and the nursery stock industries to be the most reliable way of assessing the nutritional status of the plant. For HNS producers to take advantage of this work regular analysis of both substrate and plant should take place to enable the crop to be monitored and for adjustments to be made.

The timing of nutrient applications is one method of altering the type of growth. Plants starting to grow in the spring rely on stored nutrients from the previous year and it has become standard practice to apply nutrients in the spring thus accommodating this flush of growth. Meyer and Tukey (1965) working with Taxus media Hicksii and Forsythia intermedia "Spring Glory" demonstrated that N, P and K levels found in dormant plants reflected the amount of growth produced in the following spring. Good and Tukey (1969) demonstrated nutrient uptake by dormant plants when soil temperature was above freezing, the principle nutrient utilised was nitrogen while phosphorus and potassium were fixed by the soil.

The results of this work when applied to container grown crops would suggest that although the temperature dependent release pattern of CRF's is overall most useful there are times when additional feeding could be beneficial. The use of liquid feeding during the dormant phase will enhance spring growth although autumn application could encourage soft growth which could be subject to winter damage. In the field, nitrogen can safely be applied throughout July without promoting susceptible growth and it is probable that while dormant and the soil temperature is above freezing the application or maintenance of nitrogen levels will improve spring growth. For this to be practical and environmentally acceptable a slow-release nitrogen product would be required.

TYPES OF NUTRITION

Other than the use of CRF's there are many alternative ways of providing container grown plants with adequate nutrition. These all require considerably more attention to detail but can provide a means by which the plants requirement is met more successfully. The compromise situation is where the CRF is used to provide a background level of nutrition which is topped-up by overhead liquid feeding. The water which drains away from the area or leaches from the container is then regarded as polluted and unless recycled with careful monitoring can be a problem. Liquid feeding through a sand bed is likely to cause not only a monitoring nightmare but also 'hot-spots' of high conductivity within the bed.

Foliar feeding of container-grown plants remains an alternative used only infrequently and often when a nutritional deficiency is exhibited. The expression of a nutritional deficiency is the only outward sign of an inadequacy. Routine foliar analysis and maintenance of optimum levels by foliar feeding can prevent micro and macro nutrient deficiencies appearing. The inadequacy of one nutrient may well be the limiting factor to optimum growth.

The types of foliar feed available are numerous, ranging from organic seaweed extracts to complex chelated products. It should not be assumed that a product sold as a liquid feed is necessarily the most suitable as a foliar feed.

Many species have a thick waxy cuticle requiring the inclusion of, at least, a non-ionic wetter. The type of adjuvant may also influence the effectiveness of the foliar feed. The use of highly refined mineral oils, stickers, extenders or penetrating, acidifying surfactants are available and could prove particularly suitable for extending the period of time for the absorption of nutrients.

The type of nutrition for plants raised in the open ground is particularly diverse but no data can be found to show or provide a suggestion as to any advantage by using either:

* straight fertilisers
* agricultural compounds
* fertigation
* CRF's

or * foliar feeding.

The practice in the USA when producing field grown, trimmed Ilex species is to time the application of nitrogen, usually in the form of urea, to just before a flush of growth. These flushes are known to occur at particular intervals during the growing season. Application at this time ensures an immediately available source of nitrogen to accommodate the plant. Other 'traditional' practices have developed over the years but no references are available in the literature searched.

COST EFFECTIVENESS

The production of fertilisers in northern Europe is in the hands of a very few companies. Increasingly these companies are becoming multi-national and therefore the price of quality fertilisers varies very little from one company to another. The major cost variable is the means by which the plants receive the nutrients. It is no coincidence that the rise in popularity of CRF's is associated with cost effectiveness compared to the alternative methods but with tighter environmental legislation across Europe other systems are being developed to ensure drainage water is not polluted by leaching.

In agriculture the practices are changing completely. Increasingly farmers are working with the so called mineral balance system where the sum of the soil fertility and plant needs dictate the amount of fertiliser given during the season. Unfortunately there is no data available on the amounts of N, P, K taken up by HNS species on which to base a programme similar to those for agricultural crops.

In the absence of this information and present day husbandry CRF's remain the most cost effective practice for container-grown species. The use of agricultural fertiliser on field grown HNS and lined out material may be adequate but could probably be improved upon. No data has been found on this topic.

METHOD OF ADJUSTMENT

Any adjustment to the nutrition of plants must be monitored very carefully. This can be done by using both leaf and substrate/soil analysis. The method by which the nutrition is adjusted will depend to a large extent on the type of production ie container-grown, field-grown, polythene tunnel etc. If liquid feeding is to be used water-powered volumetric dosing equipment will be the most versatile. When dry fertiliser is being applied to containers the use of CRF tablets is both accurate and quick. For field-grown stock fertigation, by way of cheap drip irrigation tape, in conjunction with analysis is an underrated system which HNS producers have not yet used extensively.

CHAPTER 5

SITUATION AND STAGES

Considerable effort by the fertiliser companies has been expended determining the best types, ratio and quantities of nutrients when using peat-based substrates for container growing. Trial work has been commissioned to determine the rate of CRF for propagation (Burgess 1987) and some work by the Forestry Commission (Proe 1994) on the production of trees in modules but generally the research has been very specific.

The nutrition of stock plants in the absence of detailed work Efford have achieved good growth using recommendations from the fertiliser booklet 209 for field grown nursery stock (Scott, M A, 1987).

MOTHER PLANTS

The nutrition of mother plants should be a high priority on nurseries. No data can be found on the influence of nutrition on the take of cuttings or the viability and vigour of seed except by the Forestry Commission. This data will give some general indication as to the optimum levels of nutrition for conifer mother plants propagated by cuttings.

Seed produced on trees or hedges which are deficient in one or more nutrient can be expected to produce seed which is inadequately provided for. This may be exhibited as small seed, seed with a lower viability or poor seedling vigour. No references can be found on this topic.

CUTTINGS

Work at Efford (Burgess 1987) with sun tunnel propagation demonstrated an improvement in growth compared to liquid feeding using CRF's Ficote 16:10:10 (140 day) or Osmocote Plus 16:8:12 (8-9 month) at 1 kg/m^3. Similar advantages have been shown when using modules (Scott 1985) and 5-6 month mini granules. The rate remains variable to accommodate the sensitivity of the different species. The substantial benefits of adding nutrient to the compost were shown to be easily quantifiable in terms of cutting and liner quality when bark and/or coil is included. The benefits of locking-up the nitrogen act as a safety buffer preventing damage to the unrooted cutting.

Work on Ilex crenata (Ward and Whitcomb) at Oklahoma State University demonstrated the value of nutrition during propagation to achieve the best growth and utilisation of subsequent container nutrition. In this case Osmocote and IBDU + K Frit were compared with liquid NK fertilisation, with the cuttings in a compost containing IBDU + Frit rooting better than those with Osmocote or liquid feeding.

Trial work at Efford (Scott 1985) also demonstrated the advantages of using a CRF in the propagation medium both in cutting growth and early growth following potting. Rates of CRF varied according to the medium and the method of propagating but improvements in plant take and growth were consistent.

With the use of CRF's in the propagating medium direct sticking of cuttings becomes not only possible but very cost effective.

SEEDBED

Large numbers of plants for the landscaping industry are produced from seed. Fertiliser requirements for the various species are not known but general recommendations are provided (Tables 5.1 and 5.2).

Table 5.1 Fertiliser Application Rates Applied Before Sowing or Transplanting (kg of Element ha^{-1})

CROP TYPE	NITROGEN*	PHOSPHORUS		POTASSIUM	
	Standard	**Standard**	**High+**	**Standard**	**High***
Seedbeds	(60)	55 - 65	65 - 75	100 - 120	120 - 145
Transplants	(50)	45 - 55	55 - 65	85 - 100	100 - 120

*If nitrogen is applied then a slow release formulation should be used.
+High rates used if soil reserves low or levels difficult to maintain.

Table 5.2 Top Dressing Application Rates (Kg of Element ha^{-1} y^{-1})

CROP	NITROGEN	POTASSIUM
Seedbeds	100 - 150	50 - 75
Transplants	75 - 100	35 - 50

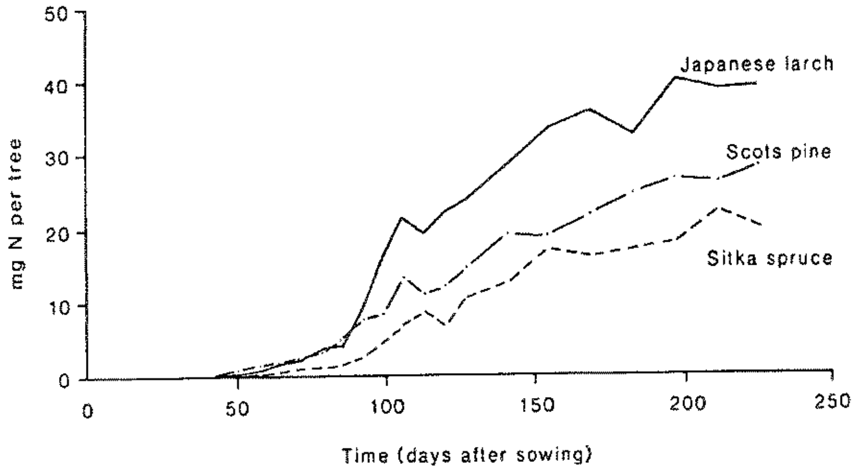
Note: A single top dressing should not apply any more than 25 kg of nitrogen ha^{-1}.

The objective of this type of production being to produce a plant with a strong fibrous root system and balanced top growth suitable for either growing on after trimming or to be lined out and bedded. The control of growth is maintained by both physical (undercutting and/or topping) and nutritional means. There is now substantial evidence that nutrient uptake continues in late summer and autumn when plant growth will be minimal. Storage of N during winter has been shown to influence growth the following spring in both sycamore and Sitka spruce (Millard and Proe 1991). Uptake of N and K late in the seasons can also increase over winter frost resistance although late season N may induce earlier flushing in the season, thereby increasing the risk of spring damage (Benzian *et al*, 1974).

Problems which arise often have to be identified quickly and corrected equally quickly to provide the full seasons uninterrupted growth. Leaf analysis is often the only way to achieve this but standards for a range of species at different ages are necessary to provide the data to make recommendations. In the absence of this data rapid diagnosis can be made by micro-nutrient, foliar application trials (Stirling, Currie 1993). These are a great deal more costly but provide standards and guidelines for future practice on individual nurseries.
In recent years, research under carefully controlled conditions has shown that much greater efficiency of fertiliser use by trees can be obtained by using frequent, low rate applications of nutrients matched to the rate of plant growth (Ingestad, 1977; Ingestad and Lund, 1986). This must however, be seen in the context of increased costs associated with multiple applications.

While it is not yet possible to predict, with any degree of confidence, the nutrient requirements for a given crop at a given time, it is becoming clear that the use of a small number of equal top dressings during the season is not the most efficient schedule. Preliminary research of container stock grown in the polyhouse clearly demonstrated that, for a range of conifer species, rates of N uptake varied markedly during the growing season (Figure 5.1). Rates of N uptake were slow for the first 10-12 weeks, followed by a short period of rapid uptake and a more extended period of moderate N uptake. Care must be taken in extrapolating such results to the open nursery seedbed where sowing densities differ between species, temperatures are lower and the vagaries of climate must be considered. The general pattern of N uptake is, however, likely to hold with only the absolute values changing. Based upon such preliminary information it is reasonable to speculate that a nitrogen top dressing regime in which the first application was reduced to provide only 20% of the season total N fertiliser, followed by a second dressing supplying 40%, a third providing 30% and a final dressing in August to make up the last 10% may prove beneficial. If more than four dressings can be applied then so much the better.

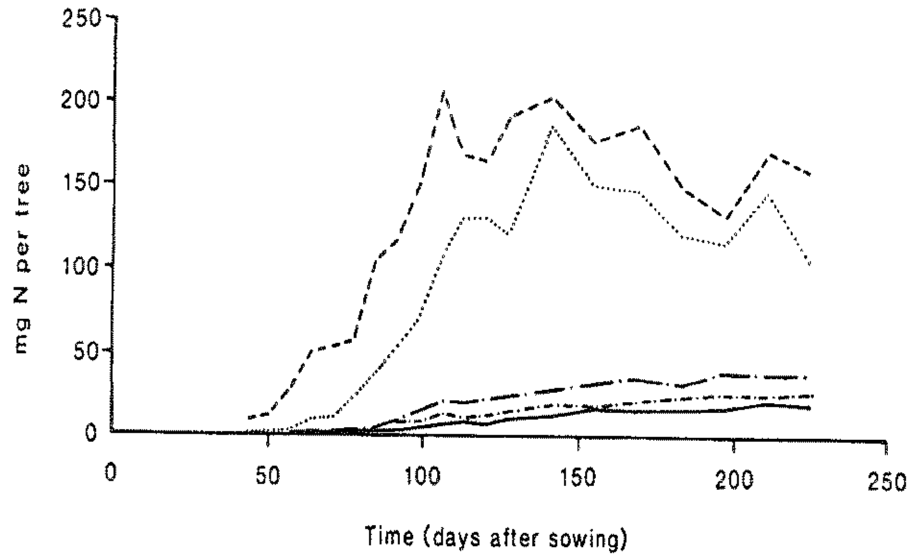
Figure 5.1 Seasonal Variation of Nitrogen in Conifers



(Proe 1994 Forest Nursery Practice, Bulletin 111).

Information on broadleaves is very limited, but the same piece of research mentioned above suggested the pattern of N uptake may be quite different (Figure 5.2). Demand for N was much greater earlier in the season. and top dressings should probably reflect this. Seedlings became 'pot-bound' approximately three months after sowing. Further research is necessary to confirm these results in open nursery seedbeds but there is already sufficient information to suggest equal top dressings throughout the growing season are likely to be inefficient. There may well be scope for greater use of the more complex slow release fertiliser compounds developed to provide a closer match between rate of nutrient supply and plant demand. However, it will still be necessary to supplement slow release products, applied at sowing or transplanting, with top dressings later in the season. One suitable regime might be to apply 50% of the annual N fertiliser as a slow release at the start of the season with a further 30% in early summer and the final 20% as a final top dressing in August (Proe 1994).

Figure 5.1 Seasonal Variation of Nitrogen in Seedlings (Data for Containerised Stock)



.... Silver Birch
----------------- Sycamore
________ Sitka Spruce
____.________ . Japanese Larch
_._._._._._._._ Scots Pine

(Proe 1994 Forest Nursery Practice, Bulletin 111).

LINER AND LINED OUT

Liner production is primarily concerned with rapid balanced growth from potting to point of sale or potting-on. The nutritional requirements are to provide for uninterrupted growth culminating in a well branched bushy plant with a reserve of nutrition to assist in swifts establishment thereafter.

Many growers use CRF's and various other "quick start", readily available fertilisers in the compost mix. This cocktail is often varied according to species eg sensitive, general or gross feeder. The nutrient requirements are not likely to be the same as for direct-sticking or for potting-on. No references have been found in the literature specifically relating to liners.

Lined out material in the field is also required to establish quickly, grow rapidly yet finish the seasons growth in time to become winter hardy. Unlike the liner production many factors influence the type and speed of growth. There is scope for responding to these variable conditions and optimising growth. This is not generally practised. A bare root transplant is caught in a "catch 22" situation with little root to absorb nutrients but requiring good roots to establish. A situation similar to vegetable transplants. The transplant must therefore have high reserves of nutrient to draw upon from within the plant. The work of Meyer and Tukey (1965) suggests that if dormant plants are fertilised the growth in the spring is improved. This may be a method by which the growth of transplants can be improved. The use of 'starter-feeds' to the transplants, as developed for vegetable production, could provide additional assistance with establishment and encourage uniform growth. Responding to the flushes of growth exhibited by many species during the season offers a method of increasing or improving the growth of lined out plants.

CELL PRODUCTION

A relatively small but increasing number of trees are produced from seed in small containers or cells. The volume of the cell ranges from 50 cm^3 for conifers to 300 cm^3 for broadleaved species. The level of nutrition for these seedlings and young plants varies with stage of growth and often a combination of CRF and liquid feeding is used to maintain growth and on occasions limit growth. As with direct sticking of cuttings the use of 'mini' formulations of CRF aids even distribution throughout the substrate but once incorporated the grower has very little control over the supply of nutrients and rate of growth.

Liquid feeding is the commonest method of fertilising tree seedlings providing the precision required for controlled growth.

Irrigation water may contain significant levels of nutrients and in formulating the feed this should be taken into account (Landis *et al* 1989).

Work by the US Department of Agriculture recommends the proportion of ammonium N should not exceed 50% of the total N within the feed solution. The balance of nutrients for cell-grown tree seedlings has been assessed by Ingestad (1979) and the ratio of 100 N: 15 P_2O_5: 80 K_2O is given. Typically concentrations of N range from 50-200 ppm depending upon the stage of growth and frequency of feeding. Trace element deficiencies are unlikely to occur if fritted trace elements have been added initially but many proprietary liquid feeds now contain a complete range of these and the addition at mixing may prove unnecessary. The use of dolomitic limestone to adjust the pH of the compost will provide an adequate base level of Mg if supplemented by liquid feeding during the season.

It would seem from the reference material that this aspect of nursery production has received considerable research and development providing adequate information for satisfactory production.

The application of the work carried out by Bigras *et al* (1989) and Still *et al* (1981) to improve the nutrient reserves within the tree going into and over winter may well have a considerable effect on subsequent growth (Section 7).

POST PRODUCTION GROWTH AND SITE

Trees moved into a landscape planting are often located in less than ideal soil conditions where soils may be thoroughly compacted from construction equipment, foot traffic or in the case of set-aside land generally unsuitable and poorly drained due to the inherent nature of the soil.

In these conditions trees, if they do survive, are slow to become established and may grow quite slowly and are more susceptible to pest problems and winter injury.

Historically, fertiliser recommendations for trees have been based on caliper of the trunk but more recently the basis has changed to branch spread or surface area. Studies have shown that tree growth is more directly related to fertiliser rate than the differences in fertiliser placement (Smith 1978).

In these trials a significant caliper increase was achieved with the addition of 2.7 kg N/100 m^2 every three years. Significant growth increases were also noted from drill hole treatments without fertiliser suggesting a direct benefit from aeration in poorly drained soils. The influence of the nutritional status of the tree at planting out ie post production, on establishment either in the field or within a landscape environment does not appear in the data search carried out.

CHAPTER 6

SUBSTRATE

The type of substrate used for HNS has over the last few years received more attention than ever before. Inert materials eg perlite, stone wool, polystyrene as a means of adjusting the porosity of the substrate are being used as well as organic materials eg bark, coir, wood waste and various processed waste products. Throughout peat, in its various forms, remains the base material. The addition of inert materials will bulk and open the peat but have very little influence on nutrient levels. Organic additives usually require the nitrogen level to be raised to compensate for the lock-up of nitrogen (Scott 1984).

The literature search revealed large numbers of references to compost mixes and additives (Bunt 1988) but only the work at Efford looked at the effect the additive has on plant nutrition.

INTERACTION BETWEEN MEDIUM AND NUTRIENTS

A wide range of peat alternatives have been developed during the last 20 years with more detailed work over the last five years as a result of the environmentalists high profile campaign. Work at Efford (Scott and Burbridge 1991) as an HDC project identified many possible waste and alternatives both organic and inorganic materials, none of which provided an immediate replacement for peat even though some would seem to have potential either as mixes with peat (coir) or as a propagation medium (rockwool, perlite). Many of these products were also identified as requiring supplementary nitrogen (N) to overcome initial lock-up (Scott, *et al*). Work on mulches and soil nitrate levels at Ohio State University (Smith *et al* 1978) identified the micro-organisms responsible for the decomposition of organic material and those which compete with plant roots for the available nitrogen when the C:N ratio is greater than 25:1. Pine bark chips, with an initial C:N ratio of 245:1 demonstrated the need for extra nitrogen to be added to prevent mulched plants becoming nitrogen deficient. Work at Efford (Scott 1984) also identified the "locking-up" abilities of bark and adjusted the fertiliser recommendation using ammonium nitrate to compensate.

The alternative organic materials will all require detailed analysis to ensure nutrition levels for the plant can be maintained throughout the season. Trials at Merristwood using pig manure composted by worms provided good results, the expected toxicity from trace elements and other toxins failed to appear although further trial work was required. The HDC screening trial set up in 1990 demonstrated phytotoxic effects from animal waste and nutrient deficiency with mixes containing coir. The importance of both compost and foliar analysis for nutrients and other known criteria will become more important if these waste products come into general use.

INERT MEDIUMS

The increased use of inert mediums such as rockwool, perlite, vermiculite, grit, slate, probase, polystyrene and clay aggregates were assessed in the HDC funded programme at Efford 1991. Many of these materials have been used for specific purposes over many years and others more recently, as the importance of air filled porosity to satisfactory plant growth has been appreciated. Those materials which have been used in the production of glasshouse salads have well documented characteristics. The characteristics, as they apply to nutrition, can be transferred to HNS production with success. Unlike glasshouse salad crops the HNS plant is required by the customer to establish in soil, the use of inert mediums may be limited to mixes with peat because of the difference in root type and consumer resistance to a new product for which the subsequent nutrition may be different.

INCORPORATION OF MYCORRHIZA

The existence of a symbiotic relationship between certain soil-inhabiting fungi and the roots of some plants has long been known, they are known to be naturally occurring in many soils including those growing conifers and a number of hardwood trees. Growers of orchids have long practised adding a portion of compost in which similar plants have grown previously as a means of transferring mycorrhizal fungi.

The three main types of mycorrhizas found on tree roots are ectomycorrhizas, endomycorhizas and ectendomcorrhizas (Walker, 1986, 1989). Ectomycorrhizas and ectendomcorrhizas occur principally with members of the Pinaceae (eg pines, firs, Douglas fir, western hemlock, larches and spruces), the Fagaceae (beeches and oaks), and the Betulaceae (birches and alders). Endomycorrhizas form with most other hardwoods (notably maples, including sycamore, cherry, ash and planes) and on members of the Cupressaceae and Taxodiaceae. A few species, such as alders and willows, can have all three kinds on the same root system.

Most of the work carried out deals with enhancing the growth of crop plants but Davies (1987) was able to show with Rosa multiflora that the inoculated medium had the greatest growth response and the greater K and Zn uptake even at zero levels of fertiliser incorporation. Where low levels of nutrients were incorporated (Osmocote 18:6:12 at 1.2 kg/m^3) greater amounts of K, Ca, S, Mn and Zn where taken up by the plants.

Nurseries producing forest trees in the UK have also inoculated the growing medium both at the seed sowing stage and at potting to advantage.

Plants grown in the inoculated substrate have in some instances exhibited a significant growth response and an increased uptake of nutrients. Their main action is to enhance mineral nutrient uptake (especially phosphorus), but they may reduce drought stress and provide protection from some pathogens (Harley and Smith, 1983). The general response is therefore to produce a bigger and healthier plant more suited to a difficult environment.

Recently, there has been an upsurge of research into the more practical aspects of the production and use of mycorrhizal inocula (Marx *et al*, 1984). Mostly, this has been with pines and Douglas fir (ectomycorrhizal species). Commercial use is limited. In the south-eastern United States, some nurseries now routinely introduce the fungus *Pisolithus tinctorius* into seedbeds before sowing loblolly pine (*Pinus taeda).* Spore-based inocula of both ectomycorrhizal fungi and AM fungi are available in the USA, as is vegetative mycelium of ectomycorrhizal fungi for incorporation into seedbeds or containers (Castellano and Molina, 1989). Such products are not yet available for ectomycorrhizas in Great Britain. Trials are being carried out on independent nurseries and have shown a reduction in the level of root disease and enhanced forest performance. Favourable results are restricted to relatively warm soils where pathogen problems necessitate fumigation of the soil. This is considered an important factor in the level of success achieved (Walker and Wheaeler 1994).

Strains of cultured *Frankia*, effective on alders, have been identified for use in Britain (Hooker and Wheeler, 1987) and their applicability has been proven at Forestry Commission research nurseries, near Edinburgh, Lothian and Farnham, Surrey (Wheeler *et al*, 1991). Inoculated plants can be sent from the nursery as 1 + 0 seedlings instead of, as is more usual, 1 + 1 transplants. Enhanced growth compared with inoculated controls can be observed for at least three years following out-planting on mine reclamation sites (McNeill *et al*, 1989 and 1990). It is important that the alders destined for planting out on reclamation land are well nodulated.

Techniques for large scale inoculation with *Frankia* are available in countries such as Canada for the inoculation of alders (Perinet *et al*, 1985). The market in Britain is not sufficiently large to justify the investment required for such a venture. Nodulation with crushed nodules is an easy and successful technique, it is recommended that seedbeds are treated in this way until commercial inoculum is available. Further information and advice on the latest situation in this fast developing method of improving plant growth can be obtained from the Forestry Authority Research Division at the Northern Research Station near Edinburgh.

CHAPTER 7

EFFECTS OF NUTRITIONAL CHANGES

WINTER HARDINESS

The ability of a plant to withstand cold conditions is influenced by growing conditions during the approach to winter, developing in two stages. The first triggered by shortening days and the second about a month later, by lower temperatures. Work in Canada (Bigras et al 1989) studied Juniperus chinensis 'Pfitxerana Aurea' grown in containers. Extending the period of fertiliser application through to October increased the N and K content in the shoots and roots and accelerated shoot growth in the spring. The prolongation of fertilisation has no influence on the total sugars or starch accumulation in shoots but did increase the levels in the roots. In an assessment of frost tolerance it was shown that shoots and roots, both young and mature, were not influenced by the late N application but again spring growth was enhanced. In these trials shoots, mature roots and young roots were hardened to -29.5^{o}C, -18.1^{o}C and -6.8^{o}C respectively at the end of November.

Similar work was carried out in Ohio (Still *et al* 1981) using Acer rubrum 'Red Sunset' with N levels applied at 50, 150 and 300 ppm from June to September. Plants fed at 150 and 300 ppm exhibited a second growth flush and the autumn colour developed three weeks later. Growth in the spring was significantly greater on trees fertilised with 300 ppm N.

The work in Canada and Ohio would suggest there is much greater potential for maximising growth both in the autumn and spring with extended feeding. In the light of previously mentioned work where N fertiliser was applied while the plants were dormant the whole concept of tree and shrub nutrition should be re-considered. The consistently hard winters in North America compared to those of the UK may well have a bearing on the results which might be obtained in the UK. Trial work to determine the effects if extended fertiliser application, in climatically different areas of the UK, are necessary.

TYPE OF GROWTH

Nutrition has played a major part in determining the type of growth achieved and which type is desirable for a particular purpose. The balance of the nutrition is recognised as being of paramount importance. The evidence from the literature search relies either on CRF or standard liquid feeding. There has been no work found on using different liquid feeds at different times of the year to achieve alternative types of growth. It cannot be assumed that the existing regimes are producing quality plants as rapidly or efficiently, especially when grown under polythene, as could be achieved.

SHELF LIFE

The increasing sales of HNS from the supermarket garden centres has led to the grower providing a product which is not only at its optimum for selling ie Rhodendron in flower, but also with a clean pot, colour label, bar coded and priced.

The longer the plant can stay in the sales area in good condition, the greater is the chance of the plant being purchased and re-ordered.

The care of plants, is or it would seem, not very high on the stores list of priorities and every care should be taken to ensure that the plants have sufficient nutrient reserves to withstand a lengthy period of neglect before the plants are bought. To achieve this adequate fertiliser reserves must exist within both the plant and the substrate. The use of foliar or substrate analysis with standards of deficient, average and adequate could become a strong selling point. No work relating to shelf life was found in the literature search but as a component of the HDC project HNS 43 (Scott, *et al*), where the longer term fertilisers showed potential to improve shelf life.

LONG-TERM EFFECTS

Throughout the literature search data is only generally available on trials over a short period of time ie two years. Work in Poland (Prusinkiewicz, *et al* 1987) was able to show that the previous type of cropping was reflected in the Scots pine, pine needle composition 85 years after planting. Although most growers are not particularly concerned with their plants after such a period and most of the species will be dead by then, it is of concern that the long term effects of either production technique or growing on area could be significant for such a period of time. The long term monitoring by soil and foliar analysis of a range of species - similar to the Rothamsted pH plots - could be included on a 'wish-list' to advantage.

AMENITY PLANTING ON AGRICULTURAL SOILS

This is a relatively new departure from both farming and forestry which has been encouraged by the Farm Woodlands Grant and other promotions. Many of the plantings have taken place on soils with a number of deficiencies as far as modern farming practice is concerned.

It is important that trees planted in these areas are of the highest quality with adequate nutrient reserves to ensure establishment. The literature search has failed to identify any work either in this country or abroad dealing specifically with this topic.

Landscape plantings of road improvements ie motorway verges, fly overs, roundabouts, cuttings, have received a higher priority in recent years but often the level of establishment is poor. This may be due to numerous factors, the state of the plants nutrient reserves being only part of the overall situation.

Controlled and slow release fertilisers are available in a tablet form to provide up to two years nutrition. The analysis of Scotts Grotab tablet is Nitrogen (N) 20%, Phosphate ($P_2 0_5$) 10%, Potassium ($K_2 0$) 5%, Calcium (Ca) 2.6%, Sulphur (S) 1.6%, Iron (Fe) 0.35%. The tablets are available as 10 g and 21 g tablets, used at the rate of 1 x 21 g tablet/2 cm trunk diameter or 1 x 21 g tablet/5 l of root volume. Recommendations are available for mature trees using either tablets or Osmocote Plus tablets.

Work by Smith (1980) on fertilising trees in the landscape over a six year period identified a caliper and growth response to the application of nitrogen, as expected, but also an improvement in growth due to drill holes 30 cm deep, 5 cm diameter, 20 per tree, in two concentric rings within a 9 m^2 area around each tree, as a result of improving aeration and drainage.

The soils used for amenity planting are often compacted and poorly drained. Consideration of these factors should take presidence over fertilisation but the combination of an improved rooting environment in conjunction with either slow or controlled release nutrition could influence establishment and subsequent growth significantly.

CHAPTER 8

MEANS OF DETERMINING NUTRITIONAL BALANCE AND METHODS OF CONTROL

The addition of nutrients to either the soil or a substrate must ensure that intensive production can be maintained. The control of a balanced nutrient supply relies upon the matching of the plants requirements and allowing for losses to the atmosphere, soil drainage, leaching etc. The balance of nutrients available to the plant may well vary according to the time of year and be manipulated to produce stock to the correct specifications. The survival establishment and early growth is also determined by the residual nutrient in the substrate and nutrient status of the plant at planting time.

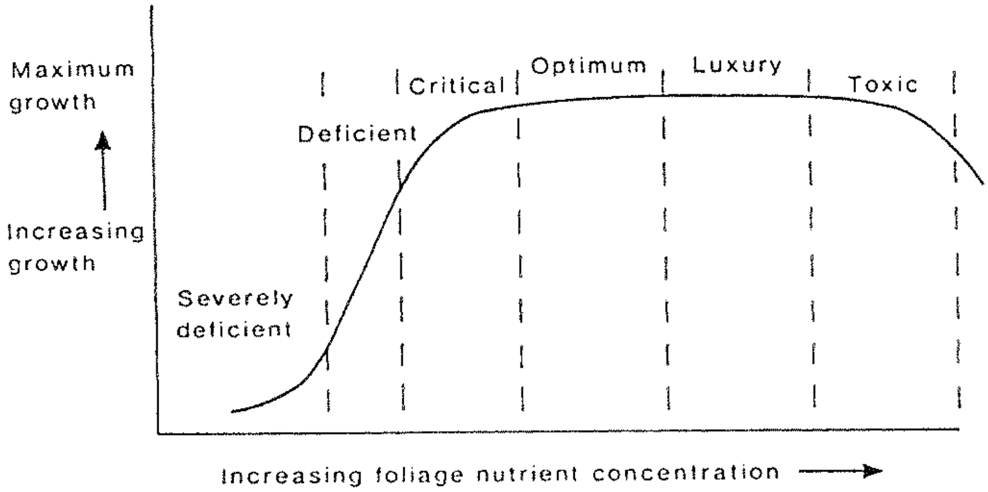
From all the work reviewed it is apparent that no one nutrient is more important than another for plant growth, though an emphasis towards or a reduction of a particular nutrient may give the desired effect (Scott, 1982).

To produce a plant which is at its optimum size and condition at the time of sale nutrient practice should compliment other cultural practices such as potting-on, protection, irrigation, undercutting etc.

The unpredictability of the climate in temperature and rainfall affect the availability of nutrients and often it is necessary to supply more nutrients than the plant requires. This is often referred to as "luxury levels". Over application can lead to toxicity eg phosphate levels referred to earlier (Scott 1982) or excessive vegetative growth. Below optimum levels where growth is restricted but deficiency symptoms are not shown probably occur frequently. As levels decline growth is further reduced and symptoms are expressed by the plant (Figure 8.1).

For field grown plants a range of nutrient concentrations are known (see Table 3.5). These values are based upon broadleaved foliage sampled in July/August or the tops of conifer seedlings taken at the end of the growing season. Variations during the season are not known and may vary considerably.

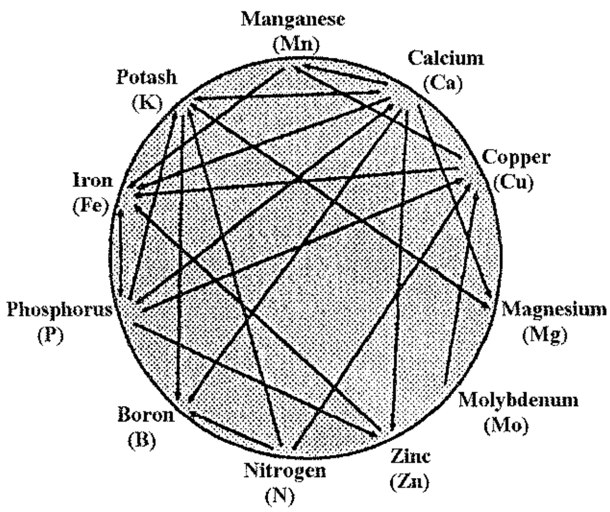
Figure 8.1 Plant Response to Increasing Nutrient Supply (Modified from Morrison, 1974)



Foliage analysis in conjunction with soil or substrate analysis therefore provides a means by which the nutrient balance can be determined and adjusted.

The correct balance between nutrients for HNS is only now starting to become apparent, that interactions are known is to the growers benefit (Figure 8.2), although the correct ratio between nutrients has yet to be determined.

Figure 8.2 Nutrient Interactions in the Soil



(Anon)

A guide to this can be found in the foliar analysis examples for particular species but the natural and induced losses will tend to confound the model prescription.

The original basis of Scott's range of CRF's was based on an NPK balance of 6:1:3 in an uninfluenced situation. After taking variables into account a ratio of 6:3:4 was chosen for the bulk of the Osmocote Plus products. Speciality products are available to accommodate the known situations where a particular ratio is required (Personal communication).

To control the nutrient balance to achieve balance or an emphasis on a particular nutrient without causing imbalance a more complete understanding of the relationship between foliar and soil analysis is required along with a knowledge of the interaction with season, site and nursery practice etc.

CHAPTER 9

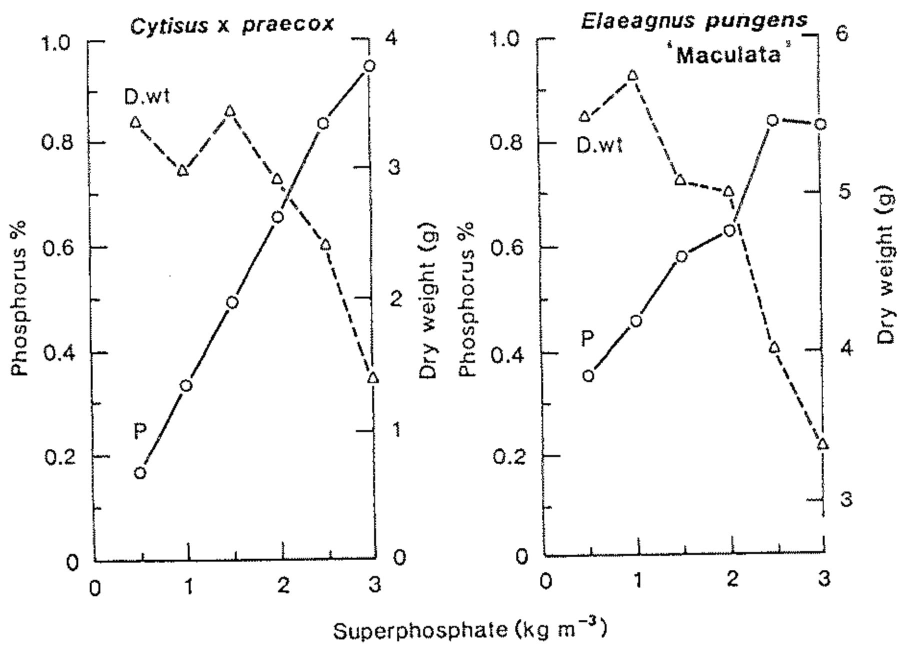
IMBALANCE PROBLEMS

NON-VISIBLE

Deficient nutrients are usually only known about when the imbalance becomes so extreme that the plant exhibits a symptom. The 'undisclosed' nutrient deficiency or nutrient imbalance is probably more common and difficult to identify. Toxicity symptoms or poor growth have been identified from work by Scott (1982) with phosphate levels. It can be seen from Figure 9.1 (Bunt, 1988), by increasing levels of phosphorus the percentage in the tissue increased but this reduced the dry weight of the plants. From this work a range of species, though not exclusive, has been identified as sensitive to phosphate, especially if the pH of the substrate increases at the same time, as could occur in a hard water area. This example of imbalance can be shown to occur with other nutrients and work is required to define the role of nutrients and their effect on plants more clearly.

Figure 9.1 Phosphorus Toxicity in Two Hardy Ornamentals Grown in a Peat-Sand Mix

Increasing rates of superphosphate increased the percentage of phosphorus in the tissue but reduced the dry weight of the plants (from Scott 1982).



Imbalance problems in glasshouse crops has been studied extensively and the effects of high nutrient levels recorded. If the amount of NPK available to the plant is increased it is quite possible that magnesium deficiency symptoms will appear. This will have been caused partly by the higher growth rate and the greater demand for Mg and partly by the antagonism which exists between potassium and magnesium; high potassium levels render magnesium less available (Bunt 1988). The complex reactions and interactions between nutrients may never be totally understood or exhibited by the plant but a reduction in growth may occur.

TISSUE ANALYSIS

Foliage sampling should be conducted on a regular basis similar to substrate or soil analysis to allow for comparative monitoring. If apparently healthy plants are sampled critical nutrient concentrations which affect plant growth can be determined and fertiliser programmes matched accordingly (Proe 1994). Sampling position ie age of leaf and time of year must be consistent and preferably standardised. There is considerable evidence that the nutrient concentration varies throughout the season (Benzian *et al* 1969) and from season to season.

SOIL ANALYSIS

Field sampling during the autumn to compile a record of nutrient status is recommended by the Forestry Authority (Bulletin 111). This should cover each distinct area or field once ever three to four years. In most cases a routine analysis will be adequate but if there is any doubt as to the level of trace-elements a full analysis is recommended. The limitations and values of soil analysis are discussed fully by Cooke (1967) considering the risks of extra polating results from one crop to another, or from one soil series to another.

It is considered that a balance between the analysis index for P, K and Mg is as important as the actual values and if either P and K or K and Mg are badly out of balance then deficiency symptoms are more likely to appear in plants. Most of the tables and experience relates to agricultural soils, with nursery soils receiving much less attention.

It is therefore important for the nursery to build up a recorded history of fertiliser application, crop growth and analysis results.

Appendix III provides tables of nutrient requirement based on soil analysis.

SUBSTRATE ANALYSIS

HNS species are mainly grown in loamless substrates requiring different conditions at different stages of production. Published guidelines do not cover all these permutations.

The analysis can cover many aspects of the substrate ie % air filled porosity, extractable nutrients, moisture retention, compacted bulk density, apart from pH and conductivity. With the widespread use of CRF's the analysis is often carried out on the sample as provided and/or a ground analysis which provides detail of the remaining amounts of nutrients in the mix.

Detailed analysis of both ground and unground mixes provides the grower with the correct information on which to base top dressing or liquid feeding decisions. Detailed recommendations can be found in the "ADAS Leaflet 643 Nutrition of Container Grown Nursery Stock". Attention should be drawn to the different methodoloy and expression of analysis data from Holland compared to the UK.

Trace element analysis from loamless substrates is often unreliable because trace elements are included as slow-release frits. The increased use of non-peat substrates is providing some evidence of both macro and micro nutrients being 'locked-up' by the media. Without tables to provide some standardisation of plant requirement the interpretation of analysis results becomes increasingly difficult (personal communication, Dr C Smith, SAC).

RELATIVE COST COMPARISON

The example below shows the cost advantage of using foliage analysis compared to substrate analysis.

(SAC Central Analytical Laboratory, Edinburgh - 7/3/95)

Tissue Analysis

Mineral Element + N Package	
N, P, K, Ca, Mg, Na, Cu, Mn, Zn, B, S and Fe	**£26.35**

Soil Analysis

Routine analysis pH, lime requirement, P, K, Mg	11.70
plus Ca, Na, Cu, Mn, Zn at £5.90 each	29.50
	£41.20

Substrate Analysis (SAC Horticultural Substrates Laboratory, Auchincruive - 7/3/95)

Routine Analysis pH, Conductivity, NH4, NO3, P, K, Mg	13.50
Plus Fe, Mn, Cu, Zn at £6.55 each	26.20
	£39.70

Water extracted samples can be analysed as for hydroponic solutions at a cost of £21.40 plus a preparation cost of £2-3. This can provide an analysis of pH, conductivity, N, P, K, Ca, Mg, Fe. Mn, Cu, B, Na.

CHAPTER 10

CONCLUSIONS

Throughout the data compilation phase of this literature review it became clear that there were very few papers dealing with basic HNS nutrition. Those that had been published and recorded in the computer databases exhibited an undercurrent of 'national knowledge' which upon closer scutiny was either non-existent or not required for the type of trial being conducted except for the contributors to the nutrition of forestry species where a considerable depth of knowledge was evident.

For an industry to expand rapidly within the UK and to develop export potential now and in the future it would seem essential that the fundamental research and development work necessary for the accurate nutrition of the product is carried out. This literature review indicates the guideline levels of leaf nutrient content for many species which if used in conjunction with substrate analysis will go a long way to ensuring a high quality end product with a long attractive shelf life.

While basic research is lacking there has been a great deal of comparative research of available products at experimental centres, on-nursery trials and within the companies themselves. Based on this information recommendations were designed, fertilisers re-formulated to improve their performance and new formulations brought on to the market to meet the needs of an industry which is becoming more specialised (Scott, 1992).

The suggestions for further R and D will compliment the existing knowledge and provide valuable information for the modern HNS specialists.

CHAPTER 11

RECOMMENDATIONS FOR FUTURE WORK

During this literature search it became apparent that very little work has been carried out on HNS in recent times. Across the world funding for HNS research and development ceased to come from governments during the 1980's and became industry financed. This type of R and D is often confidential and not with a wide horizon.

Suggestions as to the Direction of Future Research and Development

- Development of relationship tables, foliar analysis v soil or substrate levels (MAFF/HDC).
- Definition of critical nutrient threshold levels in woody ornamentals (MAFF).
- Effects of other factors on these levels (MAFF).
- Detailed investigation into the effects of nutrition on winter hardiness and subsequent growth (MAFF).
- Comprehensive work required on the nutrition of HNS grown in the field (HDC).
- Assessment of irrigation/fertigation benefits (HDC).
- Nutrition of mother plants with reference to % take etc (HDC).
- Nutrition of woody ornamental seed orchards (MAFF).
- Application of 'starter feed' technology to lined out plants (HDC).
- Growth control of cell grown plants by nutrition (HDC).

- Influence of the nutritional status of trees at planting out on establishment and subsequent growth (MAFF).

- Application of forest mycorrhizal work to HNS (HDC).

- Effects of nutrition on shelf life (HDC).

- Long term recording of soil and tissue analysis across a range of HNS species to determine the effects of nutrition and other influential factors (MAFF).

- Factors affecting tree establishment in the landscape (MAFF).

- Use of foliar feeding to add value prior to sale (HDC).

Proposals on some of these topics may be formulated by either SAC and where appropriate in association with HRI Efford.

APPENDICES

APPENDIX I

MINERAL ELEMENT VALUES OF WOODY ORNAMENTALS (Smith, 1978)

Deciduous Trees

	Percent					ppm						
	N	P	K	Ca	Mg	Mn	Fe	B	Cu	Zn	Al	Mo
Acer nigrum	1.83	0.22	0.61	2.80	0.32	212	282	46	09	26	381	2.93
Acer platanoides 'Crimson King'	2.55	0.24	1.34	1.73	0.29	030	226	42	12	25	591	1.33
Acer platanoides 'Emerald Queen'	2.80	0.34	1.33	2.57	0.35	041	330	56	14	33	689	2.58
Acer rubrum 'Schlesinger'	2.60	0.42	1.23	1.39	0.57	020	683	31	18	45	600	4.39
Acer saccharinum	2.34	0.33	0.92	1.07	0.35	144	204	26	12	43	330	2.44
Acer saccharum	2.15	0.23	0.90	1.81	0.30	030	226	52	10	26	489	1.92
Amelanchier grandiflora	1.50	0.30	1.04	1.76	0.40	050	092	18	12	26	190	2.26
Betula nigra	1.48	0.30	1.62	1.51	0.21	029	107	38	10	23	111	0.96
Betula pendula	2.52	0.27	1.46	1.36	0.22	457	140	63	16	58	203	1.10
Carpinus betulus 'Fastigiata'	2.30	0.27	0.63	2.55	0.42	452	390	54	10	29	729	3.76
Cercidiphyllum japonicum	1.82	0.29	0.69	2.32	0.33	024	083	30	10	15	212	1.70
Cercis canadensis	3.80	0.32	1.24	1.32	0.31	022	120	19	09	23	146	1.27
Cornus florida	2.24	0.21	0.61	2.42	0.08	010	033	21	13	24	916	2.08
Crataegus 'Lavelle'	1.70	0.31	1.25	1.63	0.51	046	123	25	11	36	297	2.58
Crataegus phaenopyrum	1.48	0.21	1.05	1.38	0.33	075	158	14	14	23	546	1.14
Elaeagnus augustifolius	3.50	0.34	1.14	0.78	0.26	053	246	15	12	29	514	0.63
Eucommia ulmoides	1.90	0.30	1.04	1.14	0.37	047	144	32	08	28	177	1.79
Fagus grandifolia	2.35	0.23	0.68	1.03	0.34	275	222	47	10	38	577	1.92
Fraxinus americana	2.00	0.48	0.80	2.39	0.41	032	172	29	12	18	319	3.15
Fraxinus 'Marshall 'Seedless'	2.75	0.27	1.15	1.22	0.34	028	308	19	13	27	300	1.52
Ginkbo biloba	2.55	0.49	0.97	1.55	0.74	024	404	33	10	08	282	4.03
Gleditsia triacanthos 'Moraine'	3.40	0.52	1.76	1.16	0.27	024	122	23	14	36	081	1.39
Gleditsia triacanthos 'Skyline'	3.80	0.36	1.56	1.80	0.16	041	387	32	16	26	272	0.66
Gleditsia triacanthos 'Sunburst'	4.15	0.51	1.95	1.83	0.24	043	341	34	18	35	295	1.09
Gymnocladus dioicus	3.33	0.38	1.03	2.34	0.40	049	342	50	12	21	672	5.30
Liquidambar styraciflua	1.78	0.29	0.97	0.89	0.31	555	148	23	18	45	377	2.71
Lirodendron tulipifera	2.74	0.34	1.35	1.81	0.44	069	235	21	13	27	375	2.89
Magnolia loebneri 'Merrill'	3.30	0.30	1.11	1.97	0.51	428	285	45	12	35	511	4.63
Malus 'Royalty'	2.70	0.34	1.73	0.83	0.30	032	134	34	12	24	170	0.97
Malus 'Sargenti'	2.10	0.28	1.26	0.82	0.20	025	124	25	09	18	146	0.98
Ostrya virginiana	1.62	0.23	0.70	2.27	0.36	211	535	35	11	22	956	3.94
Platanus hybrida	2.85	0.48	1.43	1.29	0.56	097	570	26	19	36	242	4.82
Platanus hybrida 'Bloodgood'	1.79	0.28	0.76	1.81	0.55	064	129	28	13	23	260	4.32
Prunus serrulata 'Kanzan'	2.42	0.30	1.13	1.41	0.55	143	167	40	15	25	165	2.57
Prunus 'Thundercloud'	2.20	0.29	2.55	1.15	0.40	028	181	34	11	23	387	1.09
Pyrus calleryana 'Bradford'	2.10	0.19	1.92	1.22	0.21	039	122	19	12	22	085	0.27
Quercus rubra maxima	3.15	0.30	0.96	1.01	0.33	454	595	36	11	34	498	1.39
Quercus shumardi	1.97	0.23	0.80	1.49	0.45	290	184	33	09	28	346	2.97
Quercus palustris 'Sovereign'	1.97	0.26	0.97	0.99	0.28	218	139	19	11	43	213	1.55
Saphora japonica	3.55	0.43	1.49	1.92	0.49	044	669	45	15	33	440	3.18
Sorbus aucuparia	3.04	0.35	1.56	1.78	0.44	227	245	17	12	21	222	1.68
Tilia cordata 'Chancellor'	2.30	0.29	1.30	2.46	0.45	218	212	49	10	28	424	3.23
Tilia cordata 'Greenspire'	3.20	0.37	1.40	1.90	0.47	088	588	40	14	30	484	3.79
Tilia tomentosa	2.44	0.32	0.91	3.07	0.61	094	160	56	13	29	435	6.59
Zelkova serrata	3.10	0.39	1.56	1.06	0.26	216	302	31	11	21	190	0.90

Deciduous Shrubs and Vines

	Percent					ppm						
	N	P	K	Ca	Mg	Mn	Fe	B	Cu	Zn	Al	Mo
Berberis atropurpurea	1.64	0.38	0.70	0.99	0.21	023	291	30	15	37	609	1.45
Campsis radicans	1.97	0.34	1.25	1.08	0.42	032	216	19	24	26	069	2.17
Chaenomeles lagenaria	2.60	0.26	1.03	1.90	0.36	069	163	36	16	41	223	0.95
Cornus alba 'Siberica'	2.60	0.62	1.10	2.23	0.36	013	075	34	10	33	064	1.77
Cornus racemosa	1.82	0.31	1.18	2.95	0.58	010	082	21	09	22	155	4.79
Cornus sericea 'Flaviramea'	2.18	0.60	1.39	1.98	0.33	011	072	30	10	26	080	1.43
Cotinus coggygria	2.50	0.34	1.08	1.22	0.25	010	177	27	11	23	266	1.05
Cotoneaster apiculata	3.90	0.36	1.13	1.08	0.17	137	202	30	14	43	247	0.65
Euonymus alatus 'Compacta'	2.40	0.21	1.24	1.65	0.10	73	304	28	12	34	288	0.69
Forsythia 'Arnold Dwarf'	1.51	0.28	1.43	0.47	0.36	042	101	14	15	29	089	2.32
Forsythia intermedia spectabilis	2.16	0.27	1.40	0.87	0.26	109	102	14	22	36	058	1.18
Hamamelis virginiana	2.25	0.25	0.59	1.22	0.25	082	154	25	10	22	215	1.65
Ligustrum amurensis	1.10	0.60	1.48	1.52	0.34	058	137	21	16	40	160	1.81
Lonicera japonica 'Halliana'	2.95	0.42	2.23	1.28	0.46	572	208	29	19	86	153	2.79
Lonicera zabel	2.67	0.42	1.51	1.99	0.55	010	116	42	12	36	169	3.59
Parthenocissus quinquifolia	2.77	0.68	2.44	1.87	0.31	459	257	22	07	43	180	1.74
Philadelphus virginalis	3.09	0.42	2.64	2.14	0.51	021	121	32	13	36	139	2.09
Potentilla 'Gold Drop'	2.21	0.45	1.26	0.76	0.29	076	186	24	13	37	228	1.84
Rhamnus frangula 'Columnaris'	3.25	0.34	1.47	1.19	0.41	096	274	26	11	34	350	1.63
Rhododendron 'Cascade'	2.22	0.25	1.06	0.88	0.56	103	233	29	16	48	384	2.66
Rhododendrion mollis	1.86	0.20	0.63	1.00	0.30	119	137	28	13	31	263	1.32
Rhus aromatica	1.96	0.29	1.11	1.47	0.39	023	150	27	10	29	229	1.63
Rosa rugosa	2.27	0.70	1.30	2.12	0.43	027	152	63	12	31	204	3.76
Rosa wichuriana	1.79	0.23	0.80	1.76	0.46	198	285	58	09	34	521	4.32
Spirea japonica alpina	2.24	0.26	1.55	0.92	0.33	312	461	35	21	61	828	3.68
Spirea 'MacFarland'	1.78	0.38	1.10	0.43	0.20	059	147	19	10	33	168	1.37
Spirea nipponica 'Snowmound'	2.41	0.34	1.10	0.99	0.36	043	102	25	13	27	075	2.07
Stephanandra incisa 'Crispa'	1.76	0.14	0.60	1.44	0.47	168	217	32	07	38	359	2.47
Syringa persica	2.75	0.26	1.07	0.94	0.28	028	115	16	15	36	164	0.81
Syringa vulgaris 'Edith Cavelle'	2.08	0.27	2.35	0.71	0.45	118	119	19	14	41	071	1.43
Viburnum lantana	2.10	0.25	0.91	1.43	0.41	023	215	29	11	34	424	1.42
Viburnum plicatum	1.54	0.27	1.34	0.84	0.33	063	123	29	11	28	172	1.08
Viburnum prunifolium	1.75	0.29	1.01	1.66	0.48	021	207	27	10	33	381	2.83
Viburnum rhytidophyllum	1.70	0.24	1.14	1.41	0.40	033	334	24	13	36	615	1.98
Weigela 'Vanicekii'	2.39	0.38	1.48	1.27	0.29	016	117	28	12	33	113	1.37

Narrowleaf Evergreens

	Percent					ppm						
	N	P	K	Ca	Mg	Mn	Fe	B	Cu	Zn	Al	Mo
Chamaecyparis pisifera 'Cyanoviridis'	2.38	0.56	1.49	1.26	0.30	359	147	28	08	33	137	1.89
Juniperus horizontalis 'Bar Harbar'	2.07	0.39	1.56	1.07	0.27	276	142	15	11	36	197	1.57
Juniperus chinensis 'Pfitzeriana Compacta'	2.26	0.44	1.09	1.62	0.21	147	142	21	16	43	081	1.82
Picea abies	1.80	0.31	0.76	0.46	0.10	038	128	17	09	33	158	0.95
Picea omorika	1.26	0.23	0.89	0.23	0.06	073	109	18	26	31	168	0.53
Picea pungens	2.10	0.21	0.61	0.24	0.08	022	105	15	08	24	124	0.37
Pinus mugo mugo	1.62	0.25	0.89	0.45	0.17	099	219	26	08	38	342	1.57
Pinus ponderosa	1.71	0.27	0.80	0.29	0.23	074	184	27	08	53	287	1.35
Pinus strabus	2.28	0.30	0.87	0.22	0.08	134	095	15	14	54	164	0.56
Pinus thunbergi	1.76	0.25	0.94	0.33	0.18	124	180	30	08	47	332	0.99
Taxus media 'Browni'	2.36	0.46	1.57	0.66	0.21	567	149	27	18	78	102	0.93
Taxus media 'Hicksii'	1.80	0.39	1.87	0.59	0.18	617	345	34	16	83	330	2.11
Thuja accidentalis pyramidalis	1.96	0.36	0.83	1.58	0.28	163	169	21	20	47	123	1.28
Thuja orientalis 'Aurea Nana'	1.89	0.46	1.53	0.81	0.39	068	163	27	09	31	188	1.33
Tsuga canadensis	3.00	0.46	1.35	0.40	0.15	208	113	21	12	36	619	1.10

Broadleaf Evergreens

	Percent					ppm						
	N	P	K	Ca	Mg	Mn	Fe	B	Cu	Zn	Al	Mo
Euonymus fortunei 'Coloratus'	2.41	0.20	1.00	1.58	0.25	055	135	34	09	36	181	1.41
Euonymus fortunei vegetus	2.38	0.32	0.58	2.64	0.10	025	311	34	17	28	382	0.79
Hedera helix	2.64	0.33	2.49	0.48	0.15	059	389	26	26	50	951	0.90
Ilex crenata 'Convexa'	3.14	0.33	1.43	0.87	0.48	342	317	23	19	89	488	3.61
Ilex apaca	1.66	0.20	0.97	0.93	0.37	437	204	27	38	82	524	1.87
Leucothoe fontanesiana	1.76	0.30	0.64	4.12	0.12	016	085	43	19	35	1020	14.98
Pieris japonica	1.68	0.19	0.94	0.53	0.13	587	032	20	10	29	073	0.84
Pyracantha coccinea 'Lalandi'	2.76	0.42	1.16	1.40	0.30	028	124	35	15	54	102	1.66
Rhododendron 'Nova Zembla'	1.61	0.22	1.14	0.62	0.33	373	093	28	09	35	094	1.47
Rhododendrion 'Roseum Elegans'	1.12	0.12	1.00	0.79	0.27	156	1053	29	08	35	347	1.45
Vinca minor	2.42	0.30	1.61	1.62	0.48	053	259	41	21	46	289	2.28
Yucca filamentosa	2.41	0.20	1.00	1.58	0.25	055	135	34	09	36	181	1.41

APPENDIX II

Deciduous Species (Aendekerk, 1982)

	N		P		K		Ca		Mg		Mn	
	+	-	+	-	+	-	+	-	+	-	+	-
Acer pseudoplatanus	2.9	1.6	.47	.13	3.1	0.2	2.5	0.8	.74	.16	20	17
Buddlea davidii	3.4	2.1	.41	.06	1.8	0.4	0.8	0.3	.35	.11	68	29
Caryopteris clandonensis	2.5	2.1	.43	.09	2.6	0.3	0.9	0.2	.29	.11	46	19
Chaenomeles speciosa	2.6	1.1	.45	.06	1.8	0.2	0.7	0.2	.31	.02	70	13
Laburnum watereri	2.7	2.4	.69	.18	1.5	0.5	1.8	1.0	.34	.15	129	69
Magnolia nigra	2.4	1.0	.17	.04	2.2	0.3	2.0	0.7	.58	.13	190	15
Nothofagus antarctica	2.2	1.0	.25	.05	0.9	0.2	0.3	0.2	.15	.04	111	30
Populus nigra	3.2	1.2	1.46	.11	3.9	0.5	1.7	0.7	.79	.12	143	24
Prunus triloba	3.2	2.0	.34	.07	2.7	0.3	1.4	0.7	.62	.23	79	82
Rosa 'Queen Elizabeth'	2.7	1.4	.32	.11	2.0	0.3	2.1	0.7	.43	.11	112	13
Sambucus 'plumosa Aurea'	3.6	0.8	.85	.13	3.6	0.4	1.8	0.3	.99	.03	118	13
Skimmia japonisa	3.4	1.3	.44	.06	1.1	0.3	1.4	0.7	.36	.16	112	67
Sorbus aucuparia	2.2	1.3	.37	.11	0.8	0.3	1.2	0.8	.45	.17	47	41
Ulmus hollandica	2.6	1.5	.89	-	3.2	0.4	2.2	0.5	.43	.13	26	12
Viburnum caricephalum	2.0	0.7	.20	.11	1.2	0.3	0.8	0.6	.26	.05	77	59
Viburnum tinus	2.0	0.8	.20	.06	2.0	0.2	0.6	0.2	.32	.06	100	7

Conifer Species

	N		P		K		Ca		Mg		Mn	
	+	-	+	-	+	-	+	-	+	-	+	-
Araucaria araucana	2.0	1.1	.25	.11	1.6	0.5	0.5	0.4	.29	.06	65	23
Chamaecyparis Lawsoniana 'Alumii'	2.0	1.3	.41	.10	1.9	0.4	0.8	0.7	.32	.04	136	17
Chamaecyparis Lawsoniana 'Elwoodii'	2.1	1.3	.29	.06	1.6	0.4	0.7	0.5	.34	.10	18	14
Cupressocyparis leylandii	2.0	0.7	.31	.06	1.4	0.3	1.0	0.7	.25	.08	21	2
Ginkgo bilboa	1.9	1.4	.30	.06	1.9	0.2	1.7	0.2	.69	.20	43	12
Juniperus squamata 'Meyeri'	2.6	1.2	.36	.08	1.7	0.8	1.3	0.5	.40	.13	53	25
Juniperus virginiana 'Skyrocket'	2.8	1.4	.32	.09	1.7	0.3	0.7	0.3	.26	.04	81	13
Picea abies	1.8	0.9	.25	.07	0.8	0.1	0.5	0.4	.30	.04	24	22
Thuja occidentalis	2.1	0.8	.26	.07	1.1	0.4	1.2	0.5	.40	.10	67	19

Ericaceous Species

	N		P		K		Ca		Mg		Mn	
	+	-	+	-	+	-	+	-	+	-	+	-
Calluna vulgaris H. E. Beale	1.8	1.3	.15	.05	1.1	0.7	0.5	0.3	.21	.12	71	51
Rhododendron 'Blauws Pink'	1.6	1.0	.13	.06	1.3	0.6	0.7	0.4	.30	.16	27	22
R. 'Catawbiense'	1.1	0.7	.15	.05	1.3	0.2	0.8	0.6	.28	.15	126	15
R. 'Molle'	1.6	0.7	.37	.06	2.4	0.2	0.7	0.3	.60	.09	65	26

Adequate Ranges of Mineral Nutrient Contents in DM of Fruit Trees (From Nutritional Disorders of Plants)

%					ppm				
N	**P**	**K**	**Ca**	**Mg**	**B**	**Mo**	**Cu**	**Mn**	**Zn**
Malus domestica, Apple, middle leaves from current year's terminals in July/August									
2,20-2,80	0,18-0.30	1,10-1,60	1,30-2,00	0,20-0,35	25-50	0,10-0,30	5-12	35-100	15/20-50
Fruits-fruits-Fruto									
0,36-0,50	>0,09	0,93-1,20	>0,030	<0,035	10-24 at about 14% DM - approx 14%				
Pyrus communis, Pear, middle leaves from current year's terminals in July/August									
2,30-2,80	0,15-0,30	1,20-2,00	1,20-1,80	0,25-0,50	20-50	0,10-0,30	5-12	30-100	15/20-50
Prunus armeniaca, Apricot, middle leaves from current year's terminals in July/August									
2,20-3,20	0,18-0,35	2,00-3,20	1,20-2,50	0,30-0,60	20-60	0,10-0,30	5-12	30-100	15/20-50
Prunus avium, Sweet cherry, middle leaves from current year's terminals in June/July									
2,60-2,80	0,18-0,30	1,60-2,00	1,20-2,00	0,30-0,50	30-60	0,10-0,30	5-12	30-100	15/20-50
Prunus cerasus, Sour cherry, middle leaves from current year's terminals in June/July									
2,80-3,20	0,20-0,35	1,60-2,00	1,60-2,50	0,30-0,50	30-60	0,10-0,30	5-12	35-100	15/20-50
Prunus domestica, Plum sp., middle leaves from current year's terminals in July/August									
2,20-3,20	0,18-0,35	1,50-2,50	1,20-2,50	0,30-0,60	30-60	0,10-0,30	5-12	25-100	15/20-50
Prunus persica, Peach, middle leaves from current year's terminals in June/July									
2,20-3,20	0,18-0,35	1,50-3,00	1,50-2,50	0,30-0,60	20-60	0,10-0,30	7-15	35-100	15/25-50

%					ppm				
N	**P**	**K**	**Ca**	**Mg**	**B**	**Mo**	**Cu**	**Mn**	**Zn**
Corylus avellana, Hazel nut or stock nut, full developed mature leaves from new terminals at mid-July									
2,50-3,50	0,15-0,40	1,00-2,40	0,80-1,50	0,25-0,40	25-80	0,20-0,50	6-12	25-100	15/20-60
Juglans regia, Walnut, middle leaflet pairs from terminal shoots July/August									
2,20-3,50	0,15-0,40	1,20-3,00	0,80-1,50	0,30-0,70	30-80	0,20-0,50	5-12	30-100	15/20-60

Adequate Ranges of Mineral Nutrient Content in DM of Berry, Small or Soft Fruits

%					ppm				
N	**P**	**K**	**Ca**	**Mg**	**B**	**Mo**	**Cu**	**Mn**	**Zn**
Actinidia chinensis, Kiwifruit, youngest fully developed leaves from new terminals at mid-season									
2,50-4,50	0,20-0,40	1,80-3,00	3,00-3,50	0,35-0,50	30-50	0,05-0,20	4-10	50-150	15/20-50
Fragaria ananassa, Strawberry, youngest fully developed mature leaves at mid-season									
2,50-3,20	0,25-0,40	1,50-2,50	0,80-1,50	0,25-0,60	30-70	0,20-1,00	7-15	40-100	20-70
Ribes grossularia, Gooseberry, just fully developed mature leaves from blossoming to fruit ripening stage									
2,20-2,70	0,20-0,40	1,80-2,30	0,80-1,80	0,25-0,50	25-30	0,15-0,50	6-12	30-100	20-70
Ribes nigram, Black currant, just fully developed leaves from blossoming to fruit ripening stage									
2,60-3,20	0,20-0,40	1,80-2,30	0,80-1,80	0,25-50	25-50	0,15-50	6-12	30-100	20-70
Ribes rubrum, Red current, just fully developed leaves from blossoming to fruit ripening stage									
2,80-3,50	0,25-0,50	1,50-2,50	0,80-1,50	0,25-050	25-50	0,15-50	6-12	35-100	20-70
Rubes idaeus, Raspberry, just fully developed leaves from blossoming to fruit ripening stage									
2,80-3,50	0,25-0,50	1,80-2,50	0,80-1,50	0,30-0,60	35-80	0,20-0,50	7-15	35-100	20-70
Vitis vinifera, Grapevine, leaves opposite inflorescences at blossoming									
2,30-2,80	0,25-0,45	1,20-1,60	150-2,50 k/Mg	0,25-0,60 ≤ 6	30-60	0,15-0,50	6-12	30-100	20-25/70 P Zn 150-190

Adequate Ranges of Mineral Nutrient Contents in DM of Flowers

%					ppm				
N	**P**	**K**	**Ca**	**Mg**	**B**	**Mo**	**Cu**	**Mn**	**Zn**
Dianthus caryophyllus, Clove Pink or carnation, growth tip (about 15 cm) prior to flowering									
2,80-4,20	0,25-0,45	2,50-5,00	1,00-2,00	0,25-0,50	30-80	0,25-1,00	8-15	40-120	25-80
Hydrangea macrophylla, Hydrangea, just fully developed leaves prior to or at flowering									
2,90-4,00	0,30-0,60	2,20-3,20	0,60-1,50	0,25-0,50	20-50	0,20-0,50	6-12	30-100	20-70
Rosa, Rose, upper fully developed leaves prior to or at flowering									
2,80-4,50	0,25-0,50	1,80-3,00	1,00-1,50	0,30-0,60	30-70	0,20-1,00	7-15	35-120	25-80

Adequate Ranges of Mineral Nutrient Contents in DM of Conifers, Evergreens and Deciduous Trees

%					ppm				
N	**P**	**K**	**Ca**	**Mg**	**B**	**Mo**	**Cu**	**Mn**	**Zn**
Abies alba, Silver fir, one to two year old needles from the uppermost laterals									
1,30-1,80	0,13-0,35	0,50-1,10	0,40-1,20	0,15-0,40	20-50	0,06-0,25	5-10	50-100 (200-5000)*	15-60
Larix decidua, Larch tree, last seasons needles from the uppermost lateral									
1,60-2,30	0,15-0,30	0,50-1,10	0,60-0,90	0,12-0,30	15-50	0,05-0,20	4-10	35-200 (100-2600)*	20-80
Picea abies, Norway spruce, one to two year old needles from the uppermost laterals									
1,35-1,70	0,13-0,25	0,50-1,20	0,35-0,80	0,10-0,25	15-50	0,04-0,20	4-10	50-500 (100-3200)*	15-60
Pinus sylvestris, Scotch or Swedish fir, one to two year old needles from the uppermost laterals									
1,40-1,70	0,14-0,30	0,40-0,80	0,25-0,60	0,10-0,20	20-50	0,08-0,30	4-10	50-500 (100-1000)*	20-70
Pseudotsuga taxifolia, Douglas fir or Oregon pine, one to two year old needles from the uppermost laterals									
1,10-1,70	0,12-0,30	0,60-1,10	0,20-0,60	0,10-0,25	20-40	0,05-0,20	2-10	50-500 (500-2800)*	15-80
Taxus baccata, Yew tree, one to two year old needles from the uppermost laterals									
1,50-2,50	0,14-0,25	0,90-2,00	0,25-1,00	0,10-0,25	15-60	0,07-0,40	5-12	40-500 (100-8000)*	25-100
Acer, Maple tree or acer, fully developed leaves from current year's terminals at mid-season									
1,70-2,20	0,15-0,25	1,00-1,50	0,30-1,50	0,15-0,30	15-40	0,05-0,20	6-12	30-100	15-50

%					ppm				
N	P	K	Ca	Mg	B	Mo	Cu	Mn	Zn
Betula, Birch tree, fully developed leaves from current year's terminals at mid-season									
2,50-4,00	0,15-0,30	1,00-1,50	0,30-1,50	0,15-0,30	15-40	0,05-0,20	6-12	30-100	15-50
Fagus silvatica, Beech tree, fully developed leaves from current year's terminals at mid-season									
1,90-2,50	0,15-0,30	1,00-1,50	0,30-1,50	0,15-0,30	15-40	0,05-0,20	5-12	35-100	15-50
Fraxinux excelsior, Ash tree, fully developed leaves from current year's terminals at mid-season									
1,70-2,20	0,15-0,30	1,10-1,50	0,30-1,50	0,20-0,40	15-40	0,05-0,20	6-12	30-100	15-50
Populus, Poplar tree, fully developed leaves from current year's terminals at mid-season									
1,80-2,50	0,18-0,30	1,20-1,80	0,30-1,50	0,20-0,30	15-40	0,05-0,20	6-12	35-100	15-50
Quercus, Oak tree, fully developed leaves from current year's terminals at mid-season									
2,00-3,00	0,15-0,30	1,00-1,50	0,30-1,50	0,15-0,30	15-40	0,05-0,20	6-12	35-100	15-50
Tilia, Lime tree or linden, fully developed leaves from current year's terminals at mid-season									
2,30-2,80	0,15-0,30	1,00-1,50	0,20-1,20	0,15-0,30	15-40	0,05-0,20	6-12	35-100	15-50
Camellia sinensis, Tea plant, uppermost fully developed leaves at mid-season									
4,50-5,20	0,35-0,60	1,60-2,30	0,40-0,80	0,20-0,40	30-50	0,20-0,50	7-15	100-500?	30-80
Humulus lupulus, Hop plant, just fully developed leaves at mid-season									
2,50-3,50	0,35-0,60	2,80-3,50	1,00-2,50	0,30-0,60	25-70	0,20-0,50	6-12	30-100	35-80
Laurus nobilis, Sweet bay, just fully developed leaves									
1,60-2,40	0,10-0,20	0,55-1,00	-	0,06-0,15	-	-	-	-	

*"Normal needle or leaf nutrient levels" ("Blattspiegelwerte") according to Fiedler and Höhne (1985).

APPENDIX IV

Phosphorus Content of Soils by Analysis

ADAS ANALYSIS		Action recommended in addition to standard treatment*		MACAULAY ANALYSIS	
Analysis Results (parts per million P)	**Index**			**Analysis Results ($mg\ kg^{-1}$ P)**	**Index†**
0-9	0	Apply 1250 }		< 7	VL
		875 }	kg of ground mineral	7 - 22	L
10-15	1	625 }	phosphate per ha respectively	23 - 35	SL
16-25	2	Apply }		35 - 48	S-SL
26-45	3	standard }		48 - 109	S
46-70	4	treatment }		> 109	H
		only }			

(ADAS scale goes up to 9 but the higher indices are relevant mainly to glasshouse soils)

*Standard treatment is to add for each crop 60-120 kg ha^{-1} of P (25-30 kg ha^{-1} for greencrop)
†VL, very low; L, low; SL, slightly low; S, satisfactory; H, high.

(Forestry Commission Bulletin 111)

Potassium Content of Soils by Analysis

ADAS ANALYSIS		Action recommended in addition to standard treatment*	MACAULAY ANALYSIS	
Analysis Results (parts per million K)	**Index**		**Analysis Results ($mg\ kg^{-1}$ K)**	**Index†**
0-60	0	Top dressing with K essential especially on light soils	< 12	VL
61-120	1	Perhaps top dress with K	12 - 42	L
			42 - 66	SL
121-240	2		66 - 91	S-SL
241-400	3	No top dressings necessary	91 - 208	S
401-600	4		>208	H

(Index scale goes up to 9)

*Standard treatment is to apply 125-185 kg ha^{-1} of K in spring to each crop
†VL, very low; L, low; SL, slightly low; S, satisfactory; H, high.

(Forestry Commission Bulletin 111)

Magnesium Content of Soils by Analysis

ADAS ANALYSIS		Action recommended in addition to standard treatment*	MACAULAY ANALYSIS	
Analysis Results (parts per million Mg)	**Index**		**Analysis Results ($mg\ kg^{-1}$ Mg)**	**Index†**
0-25	0	Apply 60 kg ha^{-1} magnesium to each crop	> 12	L
26-50	1	Use magnesium limestone whenever pH has to be raised	12 - 24	SL
51-100	2	Annual magnesium applications probably not necessary. Use magnesium limestone whenever pH has to be raised	24 - 36	S-SL
101-175	3		> 36	S
176-250	4			

*Magnesium is not normally applied unless shown to be necessary by foliage discolouration or soil analysis
†L, low; SL, slightly low; S, satisfactory.

(Forestry Commission Bulletin 111)

APPENDIX V

Table 3.6

HRI EFFORD 1983 (Sampled Mid-November 1983)

SPECIES: Juniperus communis 'Repanda'

Growing Media: 75% Peat + 25% Sharp Sand

AVERAGE RATE kg/m^3	AVERAGE PLANT DRY WEIGHT (g)	% N	% P	% K	% Mg
3.3	5.7	2.5	0.2	0.7	0.3

(Sampled Mid-June 1984)

SPECIES: Juniperus communis 'Repanda'

Growing Media: 75% Peat + 25% Sharp Sand

AVERAGE RATE kg/m^3	AVERAGE PLANT DRY WEIGHT (g)	% N	% P	% K	% Mg
3.2	16.2	2	0.2	0.7	0.3

(Sampled Early December 1983)

SPECIES: Chamaecyparis lawsoniana 'Columnaris Glauca'

Growing Media: 75% Peat + 25% Sharp Sand

AVERAGE RATE kg/m^3	AVERAGE PLANT DRY WEIGHT (g)	% N	% P	% K	% Mg
3.3	22	2.2	0.4	0.9	0.3

(Sampled Mid-June 1984)

SPECIES: Chamaecyparis lawsoniana 'Columnaris Glauca'

Growing Media: 75% Peat + 25% Sharp Sand

AVERAGE RATE kg/m^3	AVERAGE PLANT DRY WEIGHT (g)	% N	% P	% K	% Mg
3.3	51	1.4	0.2	0.5	0.2

(Sampled Early December 1983)

SPECIES: X Cupressocyparis leylandii

Growing Media: 75% Peat + 25% Sharp Sand

AVERAGE RATE kg/m^3	AVERAGE PLANT DRY WEIGHT (g)	% N	% P	% K	% Mg
3.3	24.5	2	0.3	0.9	0.4

(Sampled Mid-May 1984)

SPECIES: X Cupressocyparis leylandii

Growing Media: 75% Peat + 25% Sharp Sand

AVERAGE RATE kg/m^3	AVERAGE PLANT DRY WEIGHT (g)	% N	% P	% K	% Mg
3.3	47	1.3	0.1	0.7	0.3

(Sampled Mid-November 1983)

SPECIES: Mahonia japonica

Growing Media: 75% Peat + 25% Sharp Sand

AVERAGE RATE kg/m^3	AVERAGE PLANT DRY WEIGHT (g)	% N	% P	% K	% Mg
3.3	14.5	1.9	0.2	0.7	0.2

(Sampled Mid-June 1984)

SPECIES: Mahonia japonica

Growing Media: 75% Peat + 25% Sharp Sand

AVERAGE RATE kg/m^3	AVERAGE PLANT DRY WEIGHT (g)	% N	% P	% K	% Mg
3.3	26	1.5	0.1	0.7	0.2

(Sampled Mid-November 1983)

SPECIES: Elaeagnus pungens 'Maculata'

Growing Media: 75% Peat + 25% Sharp Sand

AVERAGE RATE kg/m^3	AVERAGE PLANT DRY WEIGHT (g)	% N	% P	% K	% Mg
3.3	6.7	3.2	0.3	1.9	0.3

(Sampled Mid-May 1984)

SPECIES: Elaeagnus pungens 'Maculata'

Growing Media: 75% Peat + 25% Sharp Sand

AVERAGE RATE kg/m^3	AVERAGE PLANT DRY WEIGHT (g)	% N	% P	% K	% Mg
3.3	9.5	2.8	0.4	2	0.2

(Sampled Mid-November 1983)

SPECIES: Cytisus x praecox

Growing Media: 75% Peat + 25% Sharp Sand

AVERAGE RATE kg/m^3	AVERAGE PLANT DRY WEIGHT (g)	% N	% P	% K	% Mg
3.3	20	2.0	0.2	0.8	0.2

(Sampled Mid-May 1984)

SPECIES: Cytisus x praecox

Growing Media: 75% Peat + 25% Sharp Sand

AVERAGE RATE kg/m^3	AVERAGE PLANT DRY WEIGHT (g)	% N	% P	% K	% Mg
3.3	30	2.6	0.2	0.6	0.2

TABLE 3.61

Foliar analysis data from a trial comparing growth of a range of species in loamless compost in response to commercial available CRF's.

Substrates: 80% medium shamrock peat 20% lime free 6 mm grit
70% peat, 30% granulated pine bark + grit as ballast.

Rooted cuttings into 2 litre rigid pots in mid-May 1986. Analysis December 1986. The variation in foliage nutrients from different mediums is shown. The lack of difference between the different mediums is in part reassuring and the differences between species ie Eleagnus pungens 'Maculata' and Cytissus x praecox is of interest though probably not significant.

Table 3.61

HRI EFFORD 1986

SPECIES: Prunus laurocerasus

Growing Media: 80% Peat + 20% 6 mm Grit

AVERAGE RATE kg/m^3	AVERAGE PLANT DRY WEIGHT (g)	% N	% P	% K	% Mg	% Ca	Mn (mg/kg)	Cu (mg/kg)
5	12.6	2.6	0.3	0.7	0.4	1.1	65.2	2.8

SPECIES: Prunus laurocerasus

Growing Media: 70% Peat + 30% Cambark 100

AVERAGE RATE kg/m^3	AVERAGE PLANT DRY WEIGHT (g)	% N	% P	% K	% Mg	% Ca	Mn (mg/kg)	Cu (mg/kg)
5	15	2.7	0.3	0.9	0.4	1.3	71.7	3.8

SPECIES: X Cupressocyparis leylandii

Growing Media: 80% Peat + 20% 6 mm Grit

AVERAGE RATE kg/m^3	AVERAGE PLANT DRY WEIGHT (g)	% N	% P	% K	% Mg	% Ca	Mn (mg/kg)	Cu (mg/kg)
5	20.4	2.1	0.2	0.9	0.3	0.7	41.4	7.5

SPECIES: X Cupressocyparis leylandii

Growing Media: 70% Peat + 30% Cambark 100

AVERAGE RATE kg/m^3	AVERAGE PLANT DRY WEIGHT (g)	% N	% P	% K	% Mg	% Ca	Mn (mg/kg)	Cu (mg/kg)
5	18.8	2.1	0.3	1.1	0.3	0.8	48.2	6.8

SPECIES: Elaeagnus pungens 'Maculata'

Growing Media: 80% Peat + 20% 6 mm Grit

AVERAGE RATE kg/m^3	AVERAGE PLANT DRY WEIGHT (g)	% N	% P	% K	% Mg	% Ca	Mn (mg/kg)	Cu (mg/kg)
5	4.4	4.1	0.58	1.76	0.39	1.18	1,777	14.2

SPECIES: Elaeagnus pungens 'Maculata'

Growing Media: 70% Peat + 30% Cambark 100

AVERAGE RATE kg/m^3	AVERAGE PLANT DRY WEIGHT (g)	% N	% P	% K	% Mg	% Ca	Mn (mg/kg)	Cu (mg/kg)
5	6.48	3.81	0.56	2.25	0.41	1.55	2,175	19.5

SPECIES: Chamaecyparis pisifera 'Boulevard'

Growing Media: 80% Peat + 20% 6 mm Grit

AVERAGE RATE kg/m^3	AVERAGE PLANT DRY WEIGHT (g)	% N	% P	% K	% Mg	% Ca	Mn (mg/kg)	Cu (mg/kg)
5	13	2.99	0.38	0.85	0.49	0.86	522.5	7.92

SPECIES: Chamaecyparis pisifera 'Boulevard'

Growing Media: 70% Peat + 30% Cambark 100

AVERAGE RATE kg/m^3	AVERAGE PLANT DRY WEIGHT (g)	% N	% P	% K	% Mg	% Ca	Mn (mg/kg)	Cu (mg/kg)
5	12.89	3.14	0.37	0.96	0.49	0.83	505	7.31

SPECIES: Juniperus communis 'Repanda'

Growing Media: 80% Peat + 20% 6 mm Grit

AVERAGE RATE kg/m^3	AVERAGE PLANT DRY WEIGHT (g)	% N	% P	% K	% Mg	% Ca	Mn (mg/kg)	Cu (mg/kg)
5	13	2.57	0.27	0.75	0.40	0.69	940	6.97

SPECIES: Juniperus communis 'Repanda'

Growing Media: 70% Peat + 30% Cambark 100

AVERAGE RATE kg/m^3	AVERAGE PLANT DRY WEIGHT (g)	% N	% P	% K	% Mg	% Ca	Mn (mg/kg)	Cu (mg/kg)
5	12.89	2.52	0.28	0.80	0.35	0.72	856	6.9

SPECIES: Cytisus x praecox

Growing Media: 80% Peat + 20% 6 mm Grit

AVERAGE RATE kg/m^3	AVERAGE PLANT DRY WEIGHT (g)	% N	% P	% K	% Mg	% Ca	Mn (mg/kg)	Cu (mg/kg)
5	16.22	2.16	0.24	0.65	0.23	0.21	269	7.17

SPECIES: Cytisus x praecox

Growing Media: 70% Peat + 30% Cambark 100

AVERAGE RATE kg/m^3	AVERAGE PLANT DRY WEIGHT (g)	% N	% P	% K	% Mg	% Ca	Mn (mg/kg)	Cu (mg/kg)
5	17	2.04	0.24	0.76	0.18	0.23	186.2	5.98

TABLE 3.62

Foliar analysis results from a trial comparing different CRF's at different rates with three rates of single superphosphate added using either sand and seephose or gravel and overhead watering. The results from the 1980 and 1982 trials are tabulated according to species.

Comments

Cytissus x praecox

Dry weight improvement with seephose watering and nil extra phosphate. High levels of phosphate in substrate is also shown in the foliage analysis. A guide level for optimum growth could be assessed as between 0.2 and 0.25% P. It is interesting to note that as the % P rises in the substrate so the % K in the foliage also rises.

Chamaecyparis pisifera 'Boulevard'

This species would seem to be relatively unaffected by high phosphate levels. Manganese levels from plants grown on gravel with overhead watering are consistently lower, regardless of phosphate level, when compared to a capillary watering system. This does not occur with other nutrients as much.

Viburnum burkwoodii

Guidelines for % P in foliar analysis 0.30%. Plants watered overhead seem less effected by the high phosphate levels compared to those capillary watered.

Chamaecyparis lawsoniana 'Allumii' and Chamaecyparis 'Ellwoods Gold'

C. 'Ellwoods Gold' would seem to be affected by high phosphate levels more than C. l. 'Allumii'. In both plants the % K in the foliage is generally lower when the higher rates of phosphate are used. Guideline % P in foliar analysis 0.20%.

Camellia 'Kramers Supreme'

The foliar analysis is interesting for the high levels of manganese yet the high levels of phosphate induced severe stress reducing the plants ability to withstand disease. Guideline % P in foliar analysis 0.14%.

Skimmia japonica 'Foremanii'

Plants with high levels of phosphate in the substrate also indicated by high % P in the foliage. Increasing phosphate induced chlorosis even though the level of Fe in the foliage increased in-line with phosphate levels. A plant with a low demand for phosphate.

Elaeagnus pungens 'Maculata'

The bigger plants in the 1982 trial show a very different analysis to the 1980 plants. The high phosphate in the leaves and the plants sensitivity to phosphate is clearly indicated. Guideline % P in foliar analysis 0.20%.

Erica carnea 'Springwood White' and Calluna vulgaris 'Sunset'

Neither species affected by high phosphate levels though both are known as salt sensitive. Growth is not enhanced by higher levels of nutrition, a guideline % P in the foliar analysis of 0.1% to 0.15% would seem adequate.

Hydrangea 'Mme J de Schmedt'

A plant which exhibits chlorosis at high phosphate levels yet requires small amounts of phosphate. Iron levels increase in the foliage with increasing amounts of phosphate but not to the benefit of the plant. Guideline % P in the foliar analysis 0.3% to 0.4%.

Magnolia soulangiana

Low levels of phosphate required to maintain balanced growth. Guideline % P in foliar analysis 0.1% to 0.15%.

Japanese Azalea 'Blue Danube"

Results with Azalea published by Reuter and Robinson (1987) provide different quantified levels ie deficient, marginal, adequate, high and toxic. These are very different from the Efford results. This may be as a result of sampling differences, time and type of shoot taken. Guideline % P in foliar analysis 0.2%.

In depth statistical analysis of the complete data from HRI Efford would prove very useful in helping to compile tables comparing applied nutrients to foliar analysis. Critical nutrient thresholds could then become apparent.

Table 3.62

SPECIES: Cytisus x praecox

Bed: Sand & Seephose **Growing Media:** 75% Peat + 25% Sharp Sand **(1982)**

RATES OF SINGLE SUPER PHOSPHATE kg/m^3	AVERAGE DRY WEIGHT (g)	% N	% P	% K	% Mg	% Ca	% Mn mg/kg
Nil	35.85	1.71	0.22	0.50	0.24	0.3	508
0.75	20.8	1.63	0.71	0.79	0.28	0.35	766
1.5	11.3	2.45	1.03	0.95	0.25	0.40	987

SPECIES: Cytisus x praecox

Bed: Gravel & Overhead **Growing Media:** 75% Peat + 25% Sharp Sand **(1982)**

RATES OF SINGLE SUPER PHOSPHATE kg/m^3	AVERAGE DRY WEIGHT (g)	% N	% P	% K	% Mg	% Ca	Mn mg/kg
Nil	27.17	2.08	0.27	0.55	0.22	0.34	345
0.75	11.17	2.41	0.5	0.79	0.20	0.08	671
1.5	7.12	2.42	0.80	1.06	0.22	0.41	827

SPECIES: Cytisus x praecox

(1980)

RATES OF SINGLE SUPER PHOSPHATE kg/m^3	AVERAGE DRY WEIGHT (g)	% N	% P	% K	% Mg	% Ca	Mn mg/kg	Fe mg/g
0.5	3.3	2.23	0.16	1.15	0.28	0.36	853	86
1.0	3.3	2.18	0.37	1.13	0.25	0.39	697	104
1.5	3.26	2.17	0.56	1.37	0.25	0.41	524	102

SPECIES: Cytisus x praecox

(1980)

RATES OF SINGLE SUPER PHOSPHATE kg/m^3	AVERAGE DRY WEIGHT (g)	% N	% P	% K	% Mg	% Ca	Mn mg/kg	Fe mg/g
0.5	3.3	2.23	0.16	1.15	0.28	0.36	853	86
1.0	3.3	2.18	0.37	1.13	0.25	0.39	697	104
1.5	3.26	2.17	0.56	1.37	0.25	0.41	524	102

SPECIES: Elaeagnus pungens 'Maculata'

Bed: Sand & Seephose **Growing Media:** 75% Peat + 25% Sharp Sand **(1982)**

RATES OF SINGLE SUPER PHOSPHATE kg/m^3	AVERAGE DRY WEIGHT (g)	% N	% P	% K	% Mg	% Ca	Mn mg/kg
Nil	11.32	3.22	0.47	1.81	0.36	1.30	2,097
0.75	7.5	3.50	0.72	2.02	0.29	1.39	1,967
1.5	6.9	3.50	0.73	2.03	0.27	1.42	1,875

SPECIES: Elaeagnus pungens 'Maculata'

(1980)

RATES OF SINGLE SUPER PHOSPHATE kg/m^3	AVERAGE DRY WEIGHT (g)	% N	% P	% K	% Mg	% Ca	Mn mg/kg	Fe mg/g
0.5	5.63	2.69	0.41	2.65	0.34	1.32	2549	187
1.5	4.9	3.53	0.59	2.22	0.24	1.16	1904	143
3.0	2.43	3.08	0.81	2.31	0.24	1.31	1574	141

SPECIES: Elaeagnus pungens 'Maculata'

Bed: Gravel + Overhead **Growing Media:** 75% Peat + 25% Sharp Sand **(1982)**

RATES OF SINGLE SUPER PHOSPHATE kg/m^3	AVERAGE DRY WEIGHT (g)	% N	% P	% K	% Mg	% Ca	Mn mg/kg
Nil	9.3	2.95	0.68	1.85	0.33	1.19	2,275
0.75	6.8	3.3	0.73	2.05	0.29	1.30	2,325
1.5	5.3	3.21	0.75	2.24	0.27	1.32	2,232

SPECIES: Elaeagnus pungens 'Maculata'

Growing Media: 75% Peat + 25% Sharp Sand **(1980)**

RATES OF SINGLE SUPER PHOSPHATE kg/m³	AVERAGE DRY WEIGHT (g)	% N	% P	% K	% Mg	% Ca	Mn mg/kg	Fe mg/g
Nil	4.2	2.51	0.46	1.44	0.34	1.15	2112	173
0.75	3.95	2.55	0.73	1.52	0.34	1.33	1886.5	189.5
1.5	3.25	2.67	0.87	1.67	0.32	1.31	1673.5	177

SPECIES: Chamaecyparis pisifera 'Boulevard'

Bed: Sand & Seephose **Growing Media:** 75% Peat + 25% Sharp Sand **(1980)**

RATES OF SINGLE SUPER PHOSPHATE kg/m³	AVERAGE DRY WEIGHT (g)	% N	% P	% K	% Mg	% Ca	Mn mg/kg
Nil	18.37	2.84	0.36	0.96	0.46	0.86	1,202
0.75	17.32	2.56	0.4	0.91	0.40	0.84	1,185
1.5	17.87	2.90	0.46	0.89	0.42	1.03	1,225

SPECIES: Chamaecyparis pisifera 'Boulevard'

Bed: Gravel + Overhead **Growing Media:** 75% Peat + 25% Sharp **(1982)**

RATES OF SINGLE SUPER PHOSPHATE kg/m³	AVERAGE DRY WEIGHT (g)	% N	% P	% K	% Mg	% Ca	Mn mg/kg
Nil	17.9	2.27	0.30	0.91	0.35	0.94	890
0.75	17.15	2.29	0.34	0.90	0.36	0.90	1000
1.5	17.07	2.41	0.31	0.93	0.25	1.07	1,007.5

SPECIES: Viburnum burkwoodii

Bed: Sand & Seephose **Growing Media:** 75% Peat + 25% Sharp Sand **(1982)**

RATES OF SINGLE SUPER PHOSPHATE kg/m³	AVERAGE DRY WEIGHT (g)	% N	% P	% K	% Mg	% Ca	Mn mg/kg
Nil	12.55	2.09	0.35	0.51	0.52	1.41	727.5
0.75	9.05	2.24	0.52	0.53	0.50	1.57	802.5
1.5	7.2	2.33	0.67	0.57	0.51	1.51	812.5

SPECIES: Viburnum burkwoodii

Bed: Gravel + Overhead **Growing Media:** 75% Peat + 25% Sharp Sand **(1982)**

RATES OF SINGLE SUPER PHOSPHATE kg/m^3	AVERAGE DRY WEIGHT (g)	% N	% P	% K	% Mg	% Ca	Mn mg/kg
Nil	11.42	1.84	0.31	0.51	0.44	1.47	575
0.75	11.95	1.94	0.28	0.52	0.41	1.78	692.5
1.5	12.32	1.80	0.28	0.49	0.33	2.00	525

SPECIES: Viburnum burkwoodii

Growing Media: 75% Peat + 25% Sharp Sand **(1980)**

RATES OF SINGLE SUPER PHOSPHATE kg/m^3	AVERAGE DRY WEIGHT (g)	% N	% P	% K	% Mg	% Ca	Mn mg/kg	Fe mg/g
Nil	6.45	1.65	0.18	0.44	0.39	0.80	-	120.5
0.75	5.9	1.68	0.20	0.41	0.39	0.89	-	112
1.5	4.8	1.86	0.23	0.26	0.44	1.12	-	140

SPECIES: Chamaecyparis lawsoniana 'Allumii'

Growing Media: 75% Peat + 25% Sharp Sand **(1980)**

RATES OF SINGLE SUPER PHOSPHATE kg/m^3	AVERAGE DRY WEIGHT (g)	% N	% P	% K	% Mg	% Ca	Mn mg/kg	Fe mg/g
Nil	33.85	1.35	0.20	0.46	0.23	0.73	700	97
0.75	36.45	1.24	0.20	0.35	0.21	0.85	756	83
1.5	32.15	1.3	0.23	0.35	0.21	0.88	765	88.5

SPECIES: Chamaecyparis 'Ellwoods Gold'

Growing Media: 75% Peat + 25% Sharp Sand **(1980)**

RATES OF SINGLE SUPER PHOSPHATE kg/m^3	AVERAGE DRY WEIGHT (g)	% N	% P	% K	% Mg	% Ca	Mn mg/kg	Fe mg/g
Nil	22.3	1.47	0.41	0.92	0.25	0.75	1171	119
0.75	21.25	1.30	0.35	0.61	0.21	0.78	1092	96
1.5	15.7	1.45	0.38	0.61	0.2	0.79	1211.5	124.5

SPECIES: Camellia 'Kramers Supreme'

Growing Media: 75% Peat + 25% Sharp Sand **(1980)**

RATES OF SINGLE SUPER PHOSPHATE kg/m^3	AVERAGE DRY WEIGHT (g)	% N	% P	% K	% Mg	% Ca	Mn mg/kg	Fe mg/g
Nil	17.15	1.54	0.14	0.57	0.37	1.22	2797.5	98
0.75	13.9	1.56	0.30	0.54	0.4	1.21	2763.5	79.5
1.5	15	1.44	0.24	0.57	0.41	1.38	2692.5	75

SPECIES: Skimmia japonica 'Foremanii'

Growing Media: 75% Peat + 25% Sharp Sand **(1980)**

RATES OF SINGLE SUPER PHOSPHATE kg/m^3	AVERAGE DRY WEIGHT (g)	% N	% P	% K	% Mg	% Ca	Mn mg/kg	Fe mg/g
Nil	7.55	2.42	0.18	0.51	0.59	1.41	720	184
0.75	7.7	2.37	0.31	0.40	0.66	1.83	662.5	211
1.5	6.4	2.42	0.56	0.82	0.52	1.63	558.5	233

SPECIES: Skimmia japonica 'Foremanii'

(1980)

RATES OF SINGLE SUPER PHOSPHATE kg/m^3	AVERAGE DRY WEIGHT (g)	% N	% P	% K	% Mg	% Ca	Mn mg/kg	Fe mg/g
2.0	8.76	2.62	0.45	1.53	0.46	1.88	451	122
2.5	6.83	2.59	0.50	1.47	0.45	1.87	515	130
3.0	4.93	2.61	0.67	1.86	0.39	1.72	474	154

SPECIES: Skimmia japonica 'Foremanii'

(1980)

RATES OF SINGLE SUPER PHOSPHATE kg/m^3	AVERAGE DRY WEIGHT (g)	% N	% P	% K	% Mg	% Ca	Mn mg/kg	Fe mg/g
0.5	9.73	2.07	0.14	1.28	0.41	1.31	390	92
1.0	9.36	2.37	0.17	1.18	0.47	1.68	459	108
1.5	8.03	2.49	0.28	1.22	0.48	1.86	493	113

SPECIES: Erica carnea 'Springwood White'

Growing Media: 75% Peat + 25% Sharp Sand **(1980)**

RATES OF SINGLE SUPER PHOSPHATE kg/m^3	AVERAGE DRY WEIGHT (g)	% N	% P	% K	% Mg	% Ca	Mn mg/kg	Fe mg/g
Nil	3.75	0.86	0.15	0.44	0.29	0.43	427	118
0.75	4.1	1.87	0.21	0.51	0.27	0.45	378	141
1.5	3.35	1.86	0.25	0.63	0.27	0.51	421.5	127.5

SPECIES: Calluna vulgaris 'Sunset'

Growing Media: 75% Peat + 25% Sharp Sand **(1980)**

RATES OF SINGLE SUPER PHOSPHATE kg/m^3	AVERAGE DRY WEIGHT (g)	% N	% P	% K	% Mg	% Ca	Mn mg/kg	Fe mg/g
Nil	2.75	1.49	0.16	0.37	0.16	0.46	-	-
0.75	2.45	1.56	0.16	0.41	0.17	0.48	-	-
1.5	2.5	1.38	0.18	0.29	0.17	0.48	-	-

SPECIES: Calluna vulgaris 'Sunset'

(1980)

RATES OF SINGLE SUPER PHOSPHATE kg/m^3	AVERAGE DRY WEIGHT (g)	% N	% P	% K	% Mg	% Ca	Mn mg/kg	Fe mg/g
0.5	1.83	1.52	0.12	0.55	0.13	0.38	762	352
1.5	1.33	1.47	0.12	0.46	0.13	0.48	788	411
3.0	1.13	1.54	0.14	0.49	0.14	0.48	769	404

SPECIES: Hydrangea 'Mme J de Schmedt'

Growing Media: 75% Peat + 25% Sharp Sand **(1980)**

RATES OF SINGLE SUPER PHOSPHATE kg/m^3	AVERAGE DRY WEIGHT (g)	% N	% P	% K	% Mg	% Ca	Mn mg/kg	Fe mg/g
Nil	6.7	2.60	0.32	0.60	1.62	1.97	404	204.5
0.75	9.55	2.53	0.38	0.73	1.24	1.96	357	253.5
1.5	8.9	2.8	0.48	0.86	1.48	2.09	357	296.5

SPECIES: Hydrangea 'Mme J de Schmedt'

(1980)

RATES OF SINGLE SUPER PHOSPHATE kg/m^3	AVERAGE DRY WEIGHT (g)	% N	% P	% K	% Mg	% Ca	Mn mg/kg	Fe mg/g
0.5	8.83	2.65	0.29	3.40	-	1.01	210	102
1.0	8.43	2.98	0.31	3.69	-	1.09	203	151
1.5	7.76	2.83	0.44	3.56	-	1.06	208	124

SPECIES: Magnolia soulangiana

(1980)

RATES OF SINGLE SUPER PHOSPHATE kg/m^3	AVERAGE DRY WEIGHT (g)	% N	% P	% K	% Mg	% Ca	Mn mg/kg	Fe mg/g
0.5	14.4	1.75	0.09	1.81	0.42	1.35	881	105
1.5	10.73	2.15	0.15	1.88	0.44	1.63	1275	111
3.0	7.03	2.50	0.23	1.91	0.38	1.76	1207	137

PHOSPHATE X CRF HRI EFFORD 1981

Growing Media: 75% Peat & 25% Sand **Species:** Japanese Azalea 'Blue Danube'

SINGLE SUPERPHOSPHATE kg/m^3	AVERAGE PLANT DRY WEIGHT (g)	% N	% P	% K	% Mg	% Ca	% Mn
NIL	13.2	2.02	0.20	0.61	0.38	1.59	356
0.75	13.6	2.13	0.30	0.66	0.43	1.40	368
1.5	8.3	2.15	0.35	0.65	0.41	1.42	354

TABLE 3.63

Foliar analysis results from a trial comparing different growing mediums and varying rates of differing CRF's. Tables presented are means to highlight differences between substrates.

Cotoneaster cornubia

Samples taken in December at the end of the growing season show a high level of nitrogen in the foliage compared to the period immediately after the spring flush of growth. Other nutrients also show this pattern except % P which remains steady. This highlights the need to standardise the stage of growth at which samples are taken and to qualify at which stage the guideline levels represent.

Elaeagnus pungens 'Maculata'

The high manganese levels in this trial are again very evident at the winter sampling whereas in July levels are more 'normal'. Higher levels of N in the foliage of the plants grown in peat/sand possibly demonstrates the competition for N between the plant and the bark.

Prunus laurocerasus

Most of the foliar analysis levels are in line with other published figures but the % N of the younger plants is distinctly higher suggesting that either the substrate was running out of nutrients by July or that the older plant has a lower level in the foliage.

Chamaecyparis lawsoniana 'Stardust' and X Cupressocyparis leylandii

Both species grown in the peat/bark mix exhibit very little increase in plant dry weight between December and July yet the foliage analysis would not indicate a problem. This highlights the need to use analysis in conjunction with other indicators to present the complete picture.

Juniperus communis 'Repanda'

The average plant dry weight gain is not shown as increasing very much where as the complete data indicates that this species would seem to grow better when watered overhead and stood on gravel rather than a capillary watering system. The levels of all nutrients in the foliage show consistency throughout.

Table 3.63

HRI EFFORD 1984 (Sampled December 1984)

SPECIES: Cotoneaster cornubia

Growing Media: 75% Peat + 25% Sharp Sand

AVERAGE RATE kg/m^3	AVERAGE PLANT DRY WEIGHT (g)	% N	% P	% K	% Mg	% Ca	% Mn mg/kg
3.13	21.87	2.34	0.24	1.03	0.47	1.89	120

(Sampled December 1984)

SPECIES: Cotoneaster cornubia

Growing Media: 70% Peat + 30% Cambark 100

AVERAGE RATE kg/m^3	AVERAGE PLANT DRY WEIGHT (g)	% N	% P	% K	% Mg	% Ca	% Mn mg/kg
3.13	21.05	2.25	0.25	1.14	0.47	1.85	127

(Sampled July 1985)

SPECIES: Cotoneaster cornubia

Growing Media: 75% Peat + 25% Sharp Sand

AVERAGE RATE kg/m^3	AVERAGE PLANT DRY WEIGHT (g)	% N	% P	% K	% Mg	% Ca	% Mn mg/kg
3.13	33.05	1.58	0.22	0.89	0.40	1.45	85

(Sampled July 1985)

SPECIES: Cotoneaster cornubia

Growing Media: 75% Peat + 25% Cambark 100

AVERAGE RATE kg/m^3	AVERAGE PLANT DRY WEIGHT (g)	% N	% P	% K	% Mg	% Ca	% Mn mg/kg
3.13	32.64	1.64	0.21	0.98	0.34	1.36	91

(Sampled December 1984)

SPECIES: Elaeagnus pungens 'Maculata'

Growing Media: 75% Peat + 25% Sharp Sand

AVERAGE RATE kg/m^3	AVERAGE PLANT DRY WEIGHT (g)	% N	% P	% K	% Mg	% Ca	% Mn mg/kg
3.13	1.33	-	0.56	1.19	0.29	1.36	1316

(Sampled December 1984)

SPECIES: Elaeagnus pungens 'Maculata'

Growing Media: 70% Peat + 30% Cambark 100

AVERAGE RATE kg/m^3	AVERAGE PLANT DRY WEIGHT (g)	% N	% P	% K	% Mg	% Ca	% Mn mg/kg
3.13	1.48	-	0.56	1.29	0.27	1.39	1447

(Sampled July 1985)

SPECIES: Elaeagnus pungens 'Maculata'

Growing Media: 75% Peat + 25% Sharp Sand

AVERAGE RATE kg/m^3	AVERAGE PLANT DRY WEIGHT (g)	% N	% P	% K	% Mg	% Ca	% Mn mg/kg
3.13	0.95	4.93	0.63	1.99	0.24	0.71	313

(Sampled July 1985)

SPECIES: Elaeagnus pungens 'Maculata'

Growing Media: 70% Peat + 30% Cambark 100

AVERAGE RATE kg/m^3	AVERAGE PLANT DRY WEIGHT (g)	% N	% P	% K	% Mg	% Ca	% Mn mg/kg
3.13	1.12	4.03	0.54	1.84	0.22	0.76	282.5

(Sampled December 1984)

SPECIES: Prunus laurocerasus

Growing Media: 75% Peat + 25% Sharp Sand

AVERAGE RATE kg/m^3	AVERAGE PLANT DRY WEIGHT (g)	% N	% P	% K	% Mg	% Ca	% Mn mg/kg
3.13	11.75	2.22	0.29	0.76	0.45	1.23	54

(Sampled December 1984)

SPECIES: Prunus laurocerasus

Growing Media: 70% Peat + 30% Cambark 100

AVERAGE RATE kg/m^3	AVERAGE PLANT DRY WEIGHT (g)	% N	% P	% K	% Mg	% Ca	% Mn mg/kg
3.13	14.42	2.35	0.31	0.98	0.38	1.25	67

(Sampled July 1985)

SPECIES: Prunus laurocerasus

Growing Media: 75% Peat + 25% Sharp Sand

AVERAGE RATE kg/m^3	AVERAGE PLANT DRY WEIGHT (g)	% N	% P	% K	% Mg	% Ca	% Mn mg/kg
3.13	23.95	1.42	0.23	0.53	0.35	1.19	45

(Sampled July 1985)

SPECIES: Prunus laurocerasus

Growing Media: 70% Peat + 30% Cambark 100

AVERAGE RATE kg/m^3	AVERAGE PLANT DRY WEIGHT (g)	% N	% P	% K	% Mg	% Ca	% Mn mg/kg
3.13	22.78	1.39	0.21	0.58	0.28	1.22	52

(Sampled December 1984)

SPECIES: Chamaecyparis lawsoniana 'Stardust'

Growing Media: 75% Peat + 25% Sharp Sand

AVERAGE RATE kg/m^3	AVERAGE PLANT DRY WEIGHT (g)	% N	% P	% K	% Mg	% Ca	% Mn mg/kg
3.13	11.66	2.24	0.38	1.13	0.19	0.68	215

(Sampled December 1984)

SPECIES: Chamaecyparis lawsoniana 'Stardust'

Growing Media: 70% Peat + 30% Cambark 100

AVERAGE RATE kg/m^3	AVERAGE PLANT DRY WEIGHT (g)	% N	% P	% K	% Mg	% Ca	% Mn mg/kg
3.13	17.27	2.24	0.37	1.21	0.16	0.77	308.5

(Sampled July 1985)

SPECIES: Chamaecyparis lawsoniana 'Stardust'

Growing Media: 75% Peat + 25% Sharp Sand

AVERAGE RATE kg/m^3	AVERAGE PLANT DRY WEIGHT (g)	% N	% P	% K	% Mg	% Ca	% Mn mg/kg
3.13	22.95	1.80	0.27	0.84	0.16	0.59	100

(Sampled July 1985)

SPECIES: Chamaecyparis lawsoniana 'Stardust'

Growing Media: 70% Peat + 30% Cambark 100

AVERAGE RATE kg/m^3	AVERAGE PLANT DRY WEIGHT (g)	% N	% P	% K	% Mg	% Ca	% Mn mg/kg
3.13	19.01	1.75	0.28	1.00	0.16	0.63	145

(Sampled December 1984)

SPECIES: X Cupressocyparis leylandii

Growing Media: 75% Peat + 25% Sharp Sand

AVERAGE RATE kg/m^3	AVERAGE PLANT DRY WEIGHT (g)	% N	% P	% K	% Mg	% Ca	% Mn mg/kg
3.13	19.90	1.80	0.29	0.98	0.29	0.84	30

(Sampled December 1984)

SPECIES: X Cupressocyparis leylandii

Growing Media: 70% Peat + 30% Cambark 100

AVERAGE RATE kg/m^3	AVERAGE PLANT DRY WEIGHT (g)	% N	% P	% K	% Mg	% Ca	% Mn mg/kg
3.13	17.27	1.87	0.29	1.11	0.26	0.87	36

(Sampled July 1985)

SPECIES: X Cupressocyparis leylandii

Growing Media: 75% Peat + 25% Sharp Sand

AVERAGE RATE kg/m^3	AVERAGE PLANT DRY WEIGHT (g)	% N	% P	% K	% Mg	% Ca	% Mn mg/kg
3.13	40.72	1.12	0.18	0.61	0.26	0.81	22.94

(Sampled July 1985)

SPECIES: X Cupressocyparis leylandii

Growing Media: 70% Peat + 30% Cambark 100

AVERAGE RATE kg/m^3	AVERAGE PLANT DRY WEIGHT (g)	% N	% P	% K	% Mg	% Ca	% Mn mg/kg
3.13	19.01	1.08	0.19	0.70	0.23	0.87	29

(Sampled December 1994)

SPECIES: Juniperus communis 'Repanda'

Growing Media: 75% Peat + 25% Sharp Sand

AVERAGE RATE kg/m^3	AVERAGE PLANT DRY WEIGHT (g)	% N	% P	% K	% Mg	% Ca	% Mn mg/kg
3.13	3.17	2.34	0.23	0.48	0.28	0.59	295

(Sampled December 1994)

SPECIES: Juniperus communis 'Repanda'

Growing Media: 70% Peat + 30% Cambark 100

AVERAGE RATE kg/m^3	AVERAGE PLANT DRY WEIGHT (g)	% N	% P	% K	% Mg	% Ca	% Mn mg/kg
3.13	2.85	2.46	0.25	0.53	0.25	0.64	454

(Sampled July 1985)

SPECIES: Juniperus communis 'Repanda'

Growing Media: 75% Peat + 25% Sharp Sand

AVERAGE RATE kg/m^3	AVERAGE PLANT DRY WEIGHT (g)	% N	% P	% K	% Mg	% Ca	% Mn mg/kg
3.13	7.31	2.25	0.28	0.72	0.24	0.62	167

(Sampled July 1985)

SPECIES: Juniperus communis 'Repanda'

Growing Media: 70% Peat + 30% Cambark 100

AVERAGE RATE kg/m^3	AVERAGE PLANT DRY WEIGHT (g)	% N	% P	% K	% Mg	% Ca	% Mn mg/kg
3.13	7.02	2.03	0.27	0.75	0.21	0.65	212

TABLE 3.64

Foliar analysis results from a trial comparing the growth of a range of species in two loamless substrates using commercially available CRF's at different rates. Rooted cuttings struck in autumn 1986, potted dirtect into 2 l containers April 1987 and sampled June 1988.

These results are probably the most comprehensive of any providing guideline levels for satisfactory growth.

Table 3.64

HRI EFFORD 1987

SPECIES: Chamaecyparis pisifera 'Boulevard'

Growing Media: 80% Peat + 20% 6 mm Grit

RATE kg/m3	AVERAGE PLANT DRY WEIGHT (g)	% N	% P	% K	% Mg	% Ca	% Mn mg/kg	Cu mg/kg	B mg/kg
4.89	36.18	1.48	0.22	0.71	0.20	0.95	185	4.06	20.54

SPECIES: Chamaecyparis pisifera 'Boulevard'

Growing Media: 70% Peat + 30% Cambark 100

RATE kg/m3	AVERAGE PLANT DRY WEIGHT (g)	% N	% P	% K	% Mg	% Ca	% Mn mg/kg	Cu mg/kg	B mg/kg
4.89	31.18	1.4	0.18	0.74	0.21	1.01	291.2	4.42	21.31

SPECIES: Elaeagnus pungens 'Maculata'

Growing Media: 80% Peat + 20% 6 mm Grit

RATE kg/m3	AVERAGE PLANT DRY WEIGHT (g)	% N	% P	% K	% Mg	% Ca	% Mn mg/kg	Cu mg/kg	B mg/kg
4.89	10.40	2.00	0.14	1.34	0.17	0.94	281	7.78	41.38

SPECIES: Elaeagnus pungens 'Maculata'

Growing Media: 70% Peat + 30% Bark

RATE kg/m3	AVERAGE PLANT DRY WEIGHT (g)	% N	% P	% K	% Mg	% Ca	% Mn mg/kg	Cu mg/kg	B mg/kg
4.89	9.2	2.06	0.14	1.65	0.19	1.26	600	6.99	47.34

SPECIES: Juniperus communis 'Repanda'

Growing Media: 80% Peat + 20% 6 mm Grit

RATE kg/m^3	AVERAGE PLANT DRY WEIGHT (g)	% N	% P	% K	% Mg	% Ca	% Mn mg/kg	Cu mg/kg	B mg/kg
4.89	11.11	1.42	0.18	0.76	0.17	0.75	273	4.28	23.83

SPECIES: Juniperus communis 'Repanda'

Growing Media: 70% Peat + 30% Cambark 100

RATE kg/m^3	AVERAGE PLANT DRY WEIGHT (g)	% N	% P	% K	% Mg	% Ca	% Mn mg/kg	Cu mg/kg	B mg/kg
4.89	8.89	1.36	0.15	0.73	0.16	0.72	417	3.71	24.52

Table 3.65

CRF SCREENING HRI EFFORD 1981

Growing Media: 75% Peat & 25% Sand CRF at average rate of 3.75 kg/m^3

SPECIES	AVERAGE PLANT DRY WEIGHT (g)	% N	% P	% K	% Mg	% Ca	% Mn
Cotoneaster horizontalis	26.9	2.2	0.22	1.05	0.34	0.75	338
Eaeagnus pungens 'Maculata'	7.9	2.91	0.58	2.22	0.25	0.78	843
Chamaecyparis lawsoniana 'Ellwoods Gold"	37.35	1.28	0.25	0.64	0.17	0.54	639
Chamaecyparis pisifera 'Boulevard'	50.7	1.23	0.11	0.59	0.28	0.72	404

Table 3.66

TRACE ELEMENT TRIAL HRI EFFORD 1982

Growing Media: 75% Peat & 25% Sand

SPECIES	AVERAGE PLANT DRY WEIGHT (g)	% N	% P	% K	% Mg	Mn mg/kg	Cu mg/kg	B mg/kg	Zn mg/kg	Mo mg/kg
Viburnum burkwoodii	15.68	1.86	0.28	0.32	0.67	775	9.75	69.1	93.1	0.29
Chamaecyparis pisifera 'Boulevard'	19.50	2.28	0.29	0.62	0.44	1578	8.55	40.0	57.8	0.24
Hypericum calycinum	15.9	2.00	0.31	0.87	0.33	923	5.68	78	50	0.43
Berberis darwinii	11.76	1.61	0.16	0.62	0.16	502	4.51	40.8	39	0.59

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