RURAL INDUSTRIES RESEARCH
& DEVELOPMENT CORPORATION

Australian **Tea Tree Oil** Plant Nutritional Survey

A report for the Rural Industries Research and Development Corporation

by Dr J. E. Drinnan

July 2000

RIRDC Publication No. 00/107
RIRDC Project No. DAQ-252A

ISBN 0 642 58137 1
ISSN 1440-6845

Australian Tea Tree Oil Industry - Plant Nutritional Survey
Publication No. 00/107
Project no. DAQ-252A

Researcher Contact Details
Dr J. E. Drinnan B. Agr. Sc. PhD
28 Peters Street
MAREEBA QLD 4880

Phone: 07 4092 8555
Fax: 07 4092 3593
Email: DrinnaJE@dpi.qld.gov.au

RIRDC Contact Details
Rural Industries Research and Development Corporation
Level 1, AMA House
42 Macquarie Street
BARTON ACT 2600
PO Box 4776
KINGSTON ACT 2604

Phone: 02 6272 4539
Fax: 02 6272 5877
Email: rirdc@rirdc.gov.au
Website: http://www.rirdc.gov.au

Published in July 2000
Printed on environmentally friendly paper by Canprint

Foreword

Plantation tea tree oil production is a relatively new industry and as such there are a lot of production issues still requiring research. For Australia to maintain its dominance of the world tea tree market and remain internationally competitive producers must reduce their costs of production by optimising their production practices.

While some research work has been conducted on issues such as breeding, plant spacing and density, irrigation requirements, weed control, insect control, plant oil concentration and efficacy relatively little nutritional work has been conducted on tea tree.

This report looks at the current nutritional status and corresponding yields and fertiliser practices of tea tree grown in Australia (North Queensland and New South Wales). Some ballpark optimum fertiliser recommendations and leaf nutrient levels for tea tree are made based on nutrient removal work.

This project was funded from industry revenue which is matched by funds provided by the Federal Government and is an addition to RIRDC's diverse range of over 500 research publications It forms part of our Tea Tree Oil R&D program, which aims to support the continued development of an environmentally sustainable and profitable Australian tea tree oil industry that has established international leadership in marketing, in value-adding, and in product reliability and production.

Most of our publications are available for viewing, downloading or purchasing online through our website:

- downloads at www.rirdc.gov.au/reports/Index.htm
- purchases at www.rirdc.gov.au/eshop

Peter Core
Managing Director
Rural Industries Research and Development Corporation

Acknowledgments

The author would like to acknowledge the help and information provided by the numerous members of the Australian Tea Tree Oil Industry in Queensland and New South Wales. Without which, this project would have not been possible. Also, I would like to thank the DPI Chemistry Laboratory for conducting leaf and soil analyses.

About the Author

The principal investigator has had extensive agronomic research and development experience (including nutritional work) with a number of crops, for example, coffee, mangoes, stonefruit and tea tree. Much of this work has involved previous RIRDC funded projects. The work conducted in this project follows from a previous RIRDC funded tea tree project in North Queensland. Through these projects, the principal investigator has developed a thorough understanding of tea tree production.

Contents

Executive Summary

Background

The Australian tea tree industry is likely to face strong competition from low cost overseas producers in the near future. Also, unless the demand for tea tree oil continues to increase rapidly to meet increasing supply there is likely to be continued pressure on the price of tea tree oil. Given these circumstances, for Australia to maintain its dominance of the world tea tree market and remain internationally competitive, producers must reduce their costs of production by optimising their production practices, using elite planting material, becoming highly mechanised and increasing yields. One area highlighted by RIRDC (98/99 key issue) and the Australian Tea Tree growers association to help achieve this is to determine the nutritional requirements for maximising yields. Relatively little nutritional work has been conducted on tea tree and that which has, has occurred in NSW on fertile soils where factors other than nutrition often limit growth, so responses to fertilisers have been small.

In high production areas such as north Queensland where water, temperature and radiation are not limiting and soils are relatively infertile, and in NSW on infertile soils or where soil fertility has declined (due to a number of cropping cycles), nutrition is considered one of the major limitations to increased yields. Presently growers use nutritional information from other crops as a guide to fertiliser requirements, which is unsatisfactory. Yields have varied from 50-450kg oil/ha/year with the higher yields and oil concentrations nearly always associated with high nutritional inputs. By conducting this nutritional survey the range in types and amounts of fertiliser being used and the relationship with yields can be assessed. This information is vital before a large scale nutritional program can commence. The success of the tea tree industry has allowed many producers to diversify from Tobacco (in the Mareeba Dimbulah Irrigation Area) and from other cropping systems in other parts of Australia. This has maintained farm viability and contributed substantially to the economies of many rural towns. Improved production techniques through this project are likely to see further expansion into the industry which now has 1500ha planted on the Atherton Tablelands and 2000-4000 ha throughout the rest of Australia.

Objectives

(1) To determine the current fertilising practices and nutritional status and corresponding biomass and oil yield of tea trees grown in Australia.
(2) Develop some ballpark optimum fertiliser levels based on nutrient removal.
(3) Improve the knowledge base of the Australian producers on the nutritional requirements of tea tree.

Methodology

The survey information was collected from as many growers as possible from northern New South Wales and North Queensland on the fertiliser practices, including types, quantities and timing of fertiliser applied. Information was sought on leaf and soil nutrient levels, biomass production, oil concentrations, oil yields from crop to crop, soil type and fertility, leaf drop, irrigation levels and plant size at harvest.

This information has shown the range in quantities and types of fertilisers being applied and the resultant yields. Samples were taken for leaf and soil analysis from representative farms. Correlations between nutritional status and oil yields were studied with the aim of linking good production performance with nutritional status. The survey information was gathered via telephone interviews, personal visits and mail-outs.

Information from the survey and leaf and soil samples was collated and analysed and a fertiliser program based on nutrient removal formulated. Fertiliser treatments were then formulated for possible future nutritional work.

Outcomes

This project has increased the knowledge base of the nutritional requirements of tea tree, resulting in a better understanding by growers of the nutritional management of tea tree. The current nutritional status of the Australian industry has been documented. Results have indicated the amounts and types of fertiliser being used, the timing of application, the range in nutritional status, and the range in yields (biomass, oil concentration and oil yields) being achieved.

The optimal leaf (twig) and soil nutrient levels established provide a guide for growers to assess their fertiliser practices. Results presented allow growers to calculate the likely fertiliser requirements of their crops.

Implications

This project has indicated that there is little or no correlation between fertiliser inputs and yields. Growers are generally providing inadequate amounts of most nutrients to replace those lost through harvesting leading to a gradual decline in soil nutrients.

With the results from this project, tea tree producers should be in a better position to understand the nutritional management of tea tree. This should lead to an improvement in growth rates and oil yields as long as other constraints to growth are minimised. The increase in production should result in reduced costs of production improving the viability of tea tree production.

Recommendations

The survey data indicates no correlation between fertiliser inputs or fertility rating and the oil yield. This is surprising given the large amounts of nutrients that are removed at each harvest. As discussed many other factors influence tea tree oil yields and therefore it is often difficult to obtain clear trends from survey data. Never the less, some trends would have been expected. This creates a dilemma when setting recommendations for fertiliser use.

A conservative approach and one that will apply in the long term and be sustainable is to use sufficient fertiliser to replace the nutrients removed at harvest. In QLD, this would be around 180 kg N, 20 kg P and 220 kg K/ha/year and in NSW 130 kg N, 15 kg P and 158 kg K/ha/year. This should be applied regularly in small amounts throughout the growing season in approximately the following proportions.

Month from harvesting	% of total nutrients
0-2	10%
2-4	20%
4-6	20%
6-harvest	50%

An alternative is to assume that in the early years of a plantation, the trees can obtain sufficient nutrients from soil reserves (hence the lack of response). While this is happening, little or no fertiliser will be required. However, it is important that the plant and soil nutrient status and yield trends be closely monitored to detect when soil reserves are running down.

There is a need to conduct field trials to evaluate different levels of N, P, and K on production. From the survey results the following table is provided as a guide to fertiliser treatments.

	NSW			QLD		
	low	**mid**	**high**	**low**	**mid**	**high**
N	50	100	150 kg/ha	100	150	200 kg/ha
P	10	20	30 kg/ha	15	20	30 kg/ha
K	50	125	200 kg/ha	150	200	250 kg/ha

Fertiliser treatments need to be applied evenly throughout the growing season and other constraints on growth need to be minimised.

1. Introduction

1.1 Background

The Australian tea tree industry is likely to face strong competition from low-cost overseas producers (for example: India, China and Zimbabwe) in the near future. Also, unless the demand for tea tree oil continues to increase rapidly to meet increasing supply, there is likely to be further pressure on the price of tea tree oil. Oil has decreased in price from between $45 and $50/kg for the last few years, to $25-30/kg recently. Given these circumstances for Australia to maintain its dominance of the world tea tree market and remain internationally competitive, producers must reduce their costs of production by increasing yields.

Production figures have been highly variable ranging from 50-450 kg oil/ha/year and growth rates from 8-63 tonnes biomass/ha/year, depending on location and production techniques. This suggests that there is large scope to improve production by improving management techniques. Moisture availability, soil type (texture, fertility, depth, pH), plant density, variety, climate (rainfall, humidity, temperature) all probably affect tea tree yields to a greater extent than nutrition but once these factors are set/corrected, nutrition becomes important.

Research on many production issues have been addressed and yields have improved, however, relatively little work has been done on nutrition. The Australia Tea Tree Industry Association through the RIRDC have highlighted nutritional requirements of tea trees as an area in need of research in their 5 year strategic plan. Nutritional factors have estimated to influence yields by as much as 20-30% in North Queensland. This is brought about by a combination of higher growth rates (biomass) and an increase in oil concentration. There would be a corresponding decrease in the cost of production per kg of oil.

Fertiliser requirements of tea tree have been assumed to be very low, being an Australian native found naturally in infertile swampy soils. However, intensive plantation production has shown tea trees do require regular fertilising for maximum production. Presently, growers use nutritional information from other crops as a guide to optimum leaf levels and fertiliser requirements, which have proved unsatisfactory.

In general, the highest yields have nearly always been associated with high nutritional inputs on the most fertile soil. This survey will indicate the range in types and quantities of fertiliser being used in tea tree and if these are related to yields. It will also allow an estimate of fertiliser requirements (based on nutrient removal) to be calculated.

1.2 General Plant Nutrition

Plant growth is limited by the most limiting factor. If water availability and temperature are not limited, then responses to fertiliser should be large. If however, plants are water stressed or temperatures are low enough to impede growth responses to fertiliser will be small. The response to fertiliser is mostly due to increased growth rate, however, it is also often due to an increase in the growing season by accelerating the return to growth after winter and delaying the slow down of growth at the start of winter. In some species, there is an increase in oil concentration also.

Nutrient Analysis

Regular soil and leaf analysis is necessary to check the results of fertiliser practices and plant nutrient removal. Growers can build up a useful record of crop response to fertiliser by monitoring changes in leaf and soil nutrient levels over a number of seasons in relation to previous fertiliser applications, oil and biomass yields.

Where there are not standard optimum leaf levels, a comparison of nutrient levels from a healthy and unhealthy plant will help to diagnose a nutrient problem.

Nutrient analysis can help to:

≈ diagnose deficiencies/toxicities
≈ develop a fertiliser program
≈ measure nutrient removal
≈ survey nutrient status of crops
≈ compare nutrient status between areas

In tea tree, nutrient deficiencies are hard to see because the leaves are so small.

Nutrient Removal

To develop a fertiliser program a useful starting point is to calculate the amount of nutrients removed in the harvested portion of the crop. The amount of nutrients removed will depend on % minerals in the plant tissue, which is a function of the soil nutrient levels and level of fertiliser applied.

The harvested yield is often the dominant factor in determining nutrient removal but nutrient analysis, soil fertility and crop variety can effect the level of nutrient removal as well. Nevertheless, for practical purposes, the range in nutrient levels multiplied by the range in yield levels can be used as a guide in planning a fertiliser program. For a sustainable production system, the nutrients removed should, at very least, be replaced.

As well as nutrient removal in plant material, allowances for leaching, fixation to the soil, volatilisation, erosion and nutrients tied up in plants (trunk, roots) need to be made.

It has been estimated by a DPI project in Bananas in North Queensland that nutrient removal rates need to be increased by:

N increase rates by 30%
P increase rates by 100%
K increase rates by 30%
Ca increase rates by 10%
Mg increase rates by 25%

Once the amounts of fertiliser, which need to be applied are determined the type of fertiliser to apply has to be chosen. Basically this comes down to either organic forms or inorganic forms. The organic forms (eg chicken manure, composted tea tree mulch, seaweed extracts) are generally quite low in nutrient analysis (eg N 1-2% P½-1% K½-1½%) and therefore need to be applied in large amounts. They also tend to be quite expensive per unit of elements and have slow availability.

However, the advantages of adding organic matter to the soil are improved texture, water penetration, aeration, structure, nutrient holding capacity, biological activity, weed control and slow release of nutrients over an extended period of time. The slow release of nutrients is particularly beneficial, as small amounts of fertiliser regularly appears to give the best results. Mychorryzal fungal associations with the roots of tea trees has been observed. These help in P, Mo, Cu, and Zn nutrition and are likely to be improved with the addition of organic matter to the soil.

Inorganic fertilisers are cheap, easy to apply, easy to purchase, fast acting. They can be broadcast, applied through the irrigation or applied as foliar sprays. Foliar nutrition is a good short term fast acting technique to correct deficiencies especially for immobile nutrients, however, foliar applications are not practical for providing the large amounts of the macro nutrients required.

1.3 Nutrition of Native Plants

The nutrition of native plants is a relatively new subject and little is known about the responses of the vast majority of species including Melaleuca sp. (tea tree). Many Australian natives are considered to have only a small nutrient requirement and are generally unresponsive to fertilisers.

However, Eucalyptus sp., Macadamia, Geralton wax and probably tea tree are exceptions. With the huge biomass production possible by well-managed high-density tea tree plantations (20-50 t/ha fresh weight) it is not surprising nutrient requirements will be quite high.

Some Nutritional work conducted in other crops has indicated quite high fertiliser requirements for example:

Nutrient	Macadamia[1] kg/ha/year	Eucalyptus[2] kg/ha/year	Geralton Wax[3] kg/ha/year
N	50-150 **Up to** 300	160	80
P	25-100		10
K	40-100 **Up to** 200	50-75	80

[1] Weir and Cresswell (1995); [2] Grove et al (1996); [3] Growns (1995)

Other nutrition studies on Australian native plants have allowed optimum/normal leaf and soil nutrient levels to be established (see following Table).

Optimum/normal nutrient levels in leaves and soil of Australian Natives

Nutrient	Leptospermum spp[1] leaf	Eucalyptus spp[2] leaf	Macadamia leaf[3]	Macadamia soil[3]	
N%	1.1-1.8	0.8-1.5	1.3-1.8	N (mg/kg)	>30-15
P%	0.1-0.8	0.05-0.1	0.08-0.1	P (mg/kg)	20-80
K%	0.7-1.6	0.5-0.7	0.5-0.8	K (meq/100g)	>0.5
Ca%	0.8-1.0	0.4-1.0	0.5-0.9	Ca (meq/100g)	5
S%	-	-	0.18-0.25	S (mg/kg)	10-20
Mg%	0.1-0.3	0.2-0.4	0.08-0.10	Mg (meq/100g)	1.6
Cu(mg/kg)	-	4-10	5-12	Cu (mg/kg)	0.3-10
Zn (mg/kg)	-	15-40	15-50	Zn (mg/kg)	2-10
Fe (mg/kg)	-	50-100	25-200	Fe (mg/kg)	4
B (mg/kg)	-	20-50	20-75	B (mg/kg)	1-2
				pH (water)	5.5-6.5

[1]Reuter *et al.* (1986); [2]Judd *et al.* (1996); [3]Incitec Analysis Systems. Interpretation Chart No. 256. October 1996.

Other literature has indicated that many Australian Natives have a low phosphorous requirement and low phosphorus fertiliser is generally recommended (usually less than 3%). It is often recommended to provide small amounts of nutrients regularly throughout the growing season rather than all at one time, as some species are easily burnt.

In Eucalyptus species and peppermint increasing oil concentrations have been observed as nitrogen fertiliser rates have increased, yet in other species there has been no difference (Johns *et al* 1992, Franz 1983, Hornok 1983, Mahdi 1987).

1.4 Tea Tree Nutrition

Tea trees are very hardy plants able to withstand flooding, poor soils, drought and fire however to achieve maximum yields, good soil, plentiful irrigation/rainfall, good nutrition and excellent management skills are required.

Very little work has been done on the nutritional requirements of tea tree. In other agronomic work on plant spacing and density, irrigation requirements, weed control, insect control and study of the factors affecting oil concentrations; nutrition has not been studied directly but some treatments have induced different nutritional status. In these studies there has generally been little or no response to nitrogen while other nutrients have not been studied at all. In these cases, the lack of response can usually be related to the highly fertile soils being used or other environmental or management factors limiting growth and production, rather than nutritional aspects.

Recent work by Bolton and Greenway (1995), List *et al* (1996) and Whish (1994), amongst others does provide some information. Bolton and Greenway (1995) studied the growth characteristics and leaf phosphorus levels in three melaleuca species being watered with effluent. They found that the best growth occurred in the trees receiving the most effluent plus nitrogen. Melaleuca alternifolia was able to accumulate excess phosphorus to its needs in the older leaves. Additional phosphorus did not improve growth and they concluded tea tree has a low phosphorus requirement. If phosphorus is low, the trees move phosphorus from older leaves to new leaves. Leaf levels varied from 0.17% to 1.1%.

Whish (1994) in a pot trial found that Nitrogen and phosphorus applications increased leaf dry matter production. Nitrogen levels varied from 30 to 360 kg/ha and phosphorus from 0 to 180kg/ha. They found increase nitrogen had no effect on the oil concentration in the plant but did increase the dry matter production. Phosphorus had no effect on oil concentration either; the dry matter production was highest at 45 kg/ha P. Oil quality was influenced by nutrition, an increase in N led to a decrease in Terpinen-4-ol while the level of P had no effect on quality.

List *et al* (1996) found in pot trials that there was no relationship between nutrition and yield with nitrogen and phosphorus levels having no effect on oil concentration.

1.5 Individual Nutrients

As a general rule plants have basic similarities in their behaviour to nutrient disorders and thus symptoms from crop plants can often be used as a guide for other plants (eg tea tree). In Australia, micro nutrient deficiencies of Cu, Zn, Mn, Fe and B are common.

Nitrogen

Nitrogen is used in the production of protoplasm, proteins and chlorophyll. Required in large amounts and application levels should roughly match potassium applications. If deficient plants go yellow and growth is stunted, symptoms show up in older leaves first because nitrogen is very mobile in the plant. Deficiency in native plants in the wild is generally rare.

Phosphorus

Phosphorus promotes strong root growth. Phosphate fertilisers are often recommended for early development of many crops (for example superphosphate 300 kg/ha). It doesn’t move easily in the soil and can get fixed to the soil (especially in acid and red volcanic soils) making it unavailable to the plant. When applying phosphorus fertiliser, it is recommended to incorporate it into the soil (ie before planting) and to band rather than broadcast.

Phosphorus can get locked up with iron in the soil inducing Iron deficiency which in deficient plants shows up as a purplish and bronze discolouration. Phosphorus is rarely deficient in native plants even in soils with low levels. Excess phosphorus is toxic to many Australian natives but not melaleucas, however, it doesn't seem to be required in large amounts.

Potassium

Potassium is involved in photosynthesis and is required in large amounts by plants. It is often deficient in high rainfall areas, in sandy soils and where alot of plant matter is harvested. Deficiencies in other crops have been common in much of coastal Queensland and NSW. If deficient it causes marginal necrosis of leaves.

Calcium

Calcium is important in the formation of cell walls particularly at the growing points (roots). If deficient, it can affect the use of nitrogen in the plants. Lime, dolomite or gypsum can be used (1-3 t/ha) to correct deficiencies. Calcium is often deficient in acid soils. It is not mobile in the plant and deficiencies are seen in young leaves. Deficiencies may aggravate root rot problems.

Magnesium

Magnesium is important in the formation of chlorophyll. Deficient older leaves turn yellow and can become reddish. Deficiencies are common in acid soils. Magnesium sulfate (50 kg/ha) or dolomite are used to correct deficiencies.

Sulphur

Sulphur is involved in the formation of protein and chlorophyll. Plants become yellow (especially in young leaves) and growth is stunted. It can become deficient with water logging because sulfur precipitates out with Iron or Manganese.

Copper

Copper is involved in chloroplast and protein formation. It is often deficient at high pH and on sandy leached soils (for example QLD and NSW coasts). If deficient it causes deformed and stunted growth and often cupping in leaves. Deficiencies are corrected by applying Copper Sulphate 10-20 kg/ha or foliar sprays of Copper chelate (1%). Some deficiencies of copper in tea tree have been observed in North Queensland, but more often Fe and Zn.

Zinc

Zinc is used in chlorophyll formation and is involved in production of plant hormone synthesis. It is not very mobile in the soil and is therefore often present in soil tests, but unavailable to the plant. Deficiencies are common in many crops especially where soils have a high pH and are sandy. Deficiency occurs on young growth, often as stunted small leaves, rosetting. Deficiencies in tea tree are common in North Queensland.

Organic matter is an important source of Zn. Zinc Sulfate (20 kg/ha) and Zn Chelate (1%) as a foliar spray are used to correct deficiencies. Foliar sprays are important because Zn is very immobile. 15-20 ppm is the critical leaf level in many plants. Restricted root growth can lead to deficiencies and it is common to see localised deficiencies within a field. This has been observed for tea tree grown in North Queensland.

Manganese

Manganese is used in the formation of sugars and chlorophyll and controls production of plant oils in some plants. It is rarely deficient and only so at high pH. Deficiencies occurring on young leaves first. Manganese Sulfate is used to correct deficiencies (50 kg/ha). It can be toxic if levels are high, (eg in acid soils) and if high it can effect the solubility of iron in the plant.

Iron

Iron is used in chlorophyll synthesis and is needed in small amounts continuously. Generally deficiencies are rare unless pH is high. When deficient, young leaves go yellow, pale yellow then eventually white in severe cases, the veins remain green. Deficiencies are corrected by using Iron chelate either foliar 1% or to the ground (2-5 kg/ha). Has been a common deficiency in North Queensland in tea tree. Restricted root growth following harvest and very rapid growth has led to deficiencies often localised within a field

With foliar application repeated sprays are necessary. The levels of Iron in the plant can be reduced when Mn levels are high (eg low pH and waterlogging). Better aeration will release Iron. High phosphorus can lock up Iron. Iron is often deficient in some native plants, eg Eucalyptus and Banksia.

Boron

Boron is used in protein synthesis and is important in actively growing areas and is rarely deficient. Symptoms are deformed growth. Deficiencies are corrected by using foliar sprays of Boric acid (0.1%) or borax applied to the soil (2-4 kg/ha). Acacia sp. (wattles) are affected by deficiencies.

In tea trees it has been observed that usually when one of the micro-nutrients is deficient (for example, Fe, Zn, Cu) the levels of some macro-nutrients (for example N & K) will be greatly increased due to the reduced growth rates of the trees. It is also common to see micro-nutrient deficiencies following harvest when there is very rapid growth and the root system has been reduced because of harvesting. For one to two months, trees will have trouble accessing enough nutrients especially the immobile ones to supply their needs. In these situations, foliar fertilisers will be useful.

2. Objectives

1) To determine the current fertilising practices, nutritional status and corresponding biomass and oil yield of tea trees grown in Australia.

2) Develop some ballpark optimum fertiliser levels based on nutrient removal.

3) Improve the knowledge base of the Australian producers on the nutritional requirements of tea tree.

3. Methodology

The survey information was collected from as many growers as possible from northern New South Wales and North Queensland on the fertiliser practices, including types, quantities and timing of fertiliser applications. Information was also sought on leaf and soil nutrient levels, biomass production, oil concentrations, oil yields from crop to crop, soil type and fertility, leaf drop, irrigation levels and plant size at harvest.

This information has shown the range in quantities and types of fertilisers being applied and the resultant yields. Samples were also taken for leaf and soil analysis from representative farms. Correlations between nutritional status and oil yields were studied with the aim of linking good production performance with nutritional status. The survey information was gathered via telephone interviews, personal visits and mail-outs.

Information from the survey and leaf and soil samples was collated and analysed and a fertiliser program based on nutrient removal formulated. Fertiliser treatments will then be formulated for possible future nutritional work.

4. Results

4.1 Survey

Growers from New South Wales and Queensland were surveyed via phone calls, mail-outs or personal interviews. Information was collected only from growers who had grown tea tree for several years and had harvested the same block of tea tree for a number of seasons. Altogether, information was collected form 22 growers in New South Wales and 38 growers in Queensland.

Information was collected on fertiliser practices (types, quantities and timings of fertiliser application) and the biomass and oil yields achieved. Leaf, soil and biomass fertility levels were also collected.

4.2 Current fertiliser practices - NSW

A table of results from the survey is presented in the appendix.

Fertiliser inputs varied greatly between farms (Figure 1). The amount of nitrogen used varied between 0 and 150 kg/ha/year with an average of 53 kg/ha. Phosphorus levels varied between 0 and 72 kg/ha/year with an average of 20 kg/ha and potassium levels varied between 0 and 150 kg/ha/year with an average of 61 kg/ha. This gives an average N:P:K ratio of 3:1:3.

Small amounts of the other nutrients were used by about 50% of the growers. These nutrients were mostly contained in mixed fertilisers, for example, nitrophoska blue and Ck7. A list of the fertilisers being used on tea tree in NSW is given in the following table.

FERTILISERS USED IN NEW SOUTH WALES		
Composted tea tree	Muriate Potash	Chicken manure
Q 5	Ck 66	Aftergraze
Mg SO_4	Complete Blue	Potassium nitrate
Potassium Sulphate	Crop King 88	Nitrophoska Blue
Urea	Mo Super	Ck 7

Fertiliser is applied between 1 and 3 times/crop. Although mostly only one application is made, applications generally follow harvest (September-December). Where more than one application is made, they are usually at 2-4 month intervals during the growing season up to April. Some foliar fertilisers are used and organic fertiliser is used on several farms. Based on the level of fertiliser used (N, P, K and other nutrients), the number of applications and the level of soil fertility, each farm was given an overall rating for fertility ranging between 1 and 5 (see Appendix). About 50% of farms would be considered to have good nutritional management (amount of fertiliser applied and frequency of application).

Leaf and soil analysis from NSW farms indicated the following range in nutrient levels and average levels in healthy trees. For tea tree, a leaf analysis usually really refers to a twig analysis. A sample of small twigs collected from the upper one-third of the tree excluding brand new flush material is used to determine the leaf nutrient levels and this is the sampling material used in this report for leaf analysis unless otherwise stated.

LEAF			SOIL		
Nutrient	Range	Healthy	Nutrient	Range	Healthy
N (%)	1.3-2.1	1.8	pH (water)	4.9-6.1	5.8
P (%)	0.07-0.23	0.15	N (mg/kg)	2-10	10
K (%)	0.27-1.1	1.1	P_{BRAY} (mg/kg)	7.7-40	40
Ca (%)	0.4-0.8	0.5	K (meq/100g)	0.3-0.8	0.8
S (%)	0.11-0.22	0.2	Ca (meq/100g)	6-16	8
Mg (%)	0.18-0.38	0.22	S (mg/kg)	4-13	10
Cu (mg/kg)	4-45	20	Mg (meq/100g)	4-10	4
Zn (mg/kg)	14-70	40	Cu (mg/kg)	0.4-5.0	5
Fe (mg/kg)	60-170	100	Zn (mg/kg)	0.3-5.7	5.7
Mn (mg/kg)	100-1000	200	Fe (mg/kg)	20-65	20
B (mg/kg)	25-45	35	Mn (mg/kg)	11-33	15
			B (mg/kg)	0.6-2.0	1.0
			OM (%)	1.7	1.7

Yield data (biomass, oil and oil concentration) is presented in Figure 2. Biomass yields varied from 12 to 39 t/ha/year with an average of 24 t/ha/year. Oil yields varied from 60 to 333 kg oil/ha/year with an average of 210 kg oil/ha/year. Oil concentration varied from 0.50-1.5% oil in biomass on a fresh weight basis with an average of 0.89%.

4.3 Current fertiliser practices - Qld

A table of results from the survey is presented in the appendix.

Fertiliser inputs varied greatly between farms (Figure 1) although with less variation than shown between NSW growers. More uniform soil type, irrigation and climate probably account for this. The amount of nitrogen used varied between 54 and 390 kg/ha/year with an average of 194 kg/ha. Phosphorus levels varied between 4 and 100 kg/ha/year with an average of 26 kg/ha and potassium levels varied between 15 and 300 kg/ha/year with an average of 115 kg/ha. This gives an average N:P:K ratio of 7:1:5. In Queensland, quite large amounts of other nutrients are also used and these are either components of mixed fertilisers or are added separately, for example Mg $So_{4,}$ Ca $NO_{3,}$ Cu $So_{4,}$ Fe SO_4 and Zn SO_4. A complete list of fertilisers used in Queensland on tea tree is given in the following table.

FERTILISERS USED IN QUEENSLAND		
Nitrophoska Blue	Gran am	Pivot Blue
Urea	CN 89 (Grow cane 300)	Fe SO_4
k-spray	Ck7	Cu SO_4
Liquifert k	Ck77 (s)	Zn SO_4
Liquifert P	Potassium Sulphate	Solubor
Nitram	DAP	Potassium Nitrate
Mg SO_4	Ca NO_3	

Fertilizer is applied between 2 and 26 times/crop, although mostly 4-6 applications are made. Applications generally follow harvest (which can be at any time of the year) and are spread evenly through the crop cycle until harvest. Some foliar fertilisers are used especially for trace elements for example Fe, Cu, Zn. Based on fertiliser used and the number of applications each farm was given an overall rating for fertility ranging between 1 and 5 (see appendix). Only about 16% of farms would be considered to have inadequate nutrition levels (amount of fertiliser or frequency of application).

Leaf, soil and biomass analysis from Queensland farms, indicate the following range in nutrient levels and average levels in healthy trees.

LEAF			SOIL			BIOMASS		
Nutrient	**Range**	**Healthy**	**Nutrient**	**Range**	**Healthy**	**Nutrient**	**Range**	**Healthy**
N (%)	0.9-2.2	1.9	pH (water)	4.8-6.5	5.5	N (%)	0.7-0.94	0.9
P (%)	0.06-0.40	0.1-0.2	N (mg/kg)	1-20	20	P (%)	0.06-0.1	0.1
K (%)	0.6-1.8	1.5	P colwell (mg/kg)	15-86	25	K (%)	0.87-1.2	1.1
Ca (%)	0.2-0.9	0.8	K (meq/100g)	0.05-0.32	0.3	Ca (%)	0.42-0.49	0.45
S (%)	0.1-0.5	0.2	Ca (meq/100g)	0.38-2.5	2	Mg (%)	0.12-0.16	0.15
Mg (%)	0.1-0.3	0.2	S (mg/kg)	2-30	20	S (%)	0.09-0.12	0.11
Cu (mg/kg)	0-46	10	Mg (meq/100g)	0.12-2	1.5	Cu (mg/kg)	0-10	10
Zn (mg/kg)	5-60	40	Cu (mg/kg)	0.2-10	5	Zn (mg/kg)	15-26	20
Fe (mg/kg)	0-120	50	Zn (mg/kg)	0.1-15	10	Mn (mg/kg)	170-490	180
Mn (mg/kg)	100-600	150	Fe (mg/kg)	2-59	50	Fe (mg/kg)	59-110	70
B(mg/kg)	15-40	30	Mn (mg/kg)	2-50	20	B (mg/kg)	12-24	20
			B (mg/kg)	0.1-0.3	0.2			
			OM (%)	0-0.5	0.5			

The range in leaf levels and the levels in healthy trees are similar between states. Soil levels indicate the soils are generally more fertile in NSW and have higher levels of K, Ca, Mg, B and organic matter.

Yield data (biomass, oil and oil concentration) is presented in Figure 2. Biomass yields varied from 18 to 55 t/ha/year with an average of 36.4 t/ha, or about 50% greater than NSW. Oil yields varied from 105 to 436 kg oil/ha/year with an average of 272 kg/ha, which are about 30% greater than NSW. Oil concentration varied from 0.42 to 1.06% oil in biomass on a fresh weight basis with an average of 0.74% or about 20% less than in NSW. This is probably accounted for by the smaller tree size and biomass at harvest in NSW resulting in a greater proportion of leaf matter relative to stem, hence greater amount of oil per weight of harvested material.

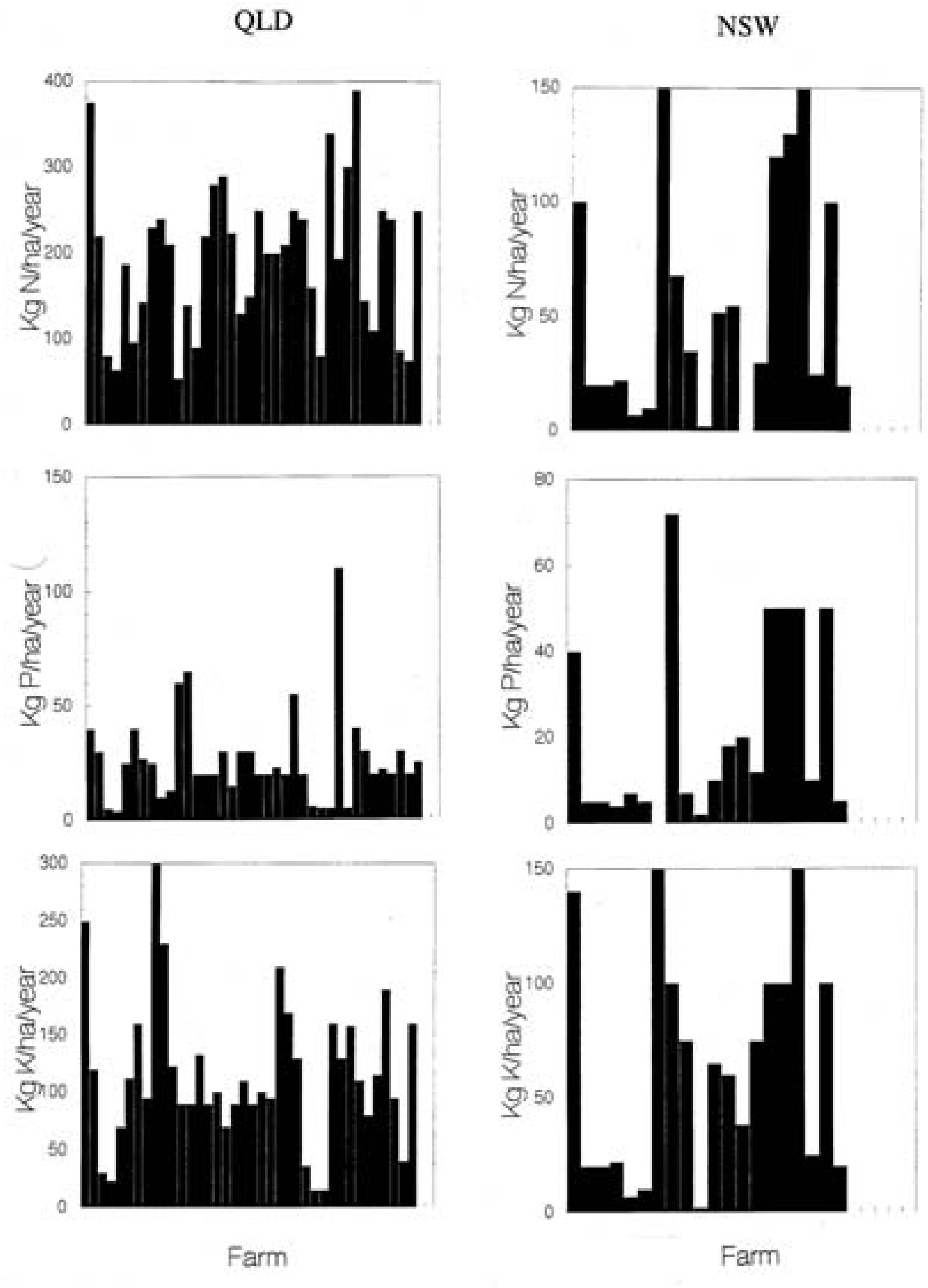


Figure 1: The amount of nitrogen, phosphorous and potassium applied per ha for each the farms in the survey.

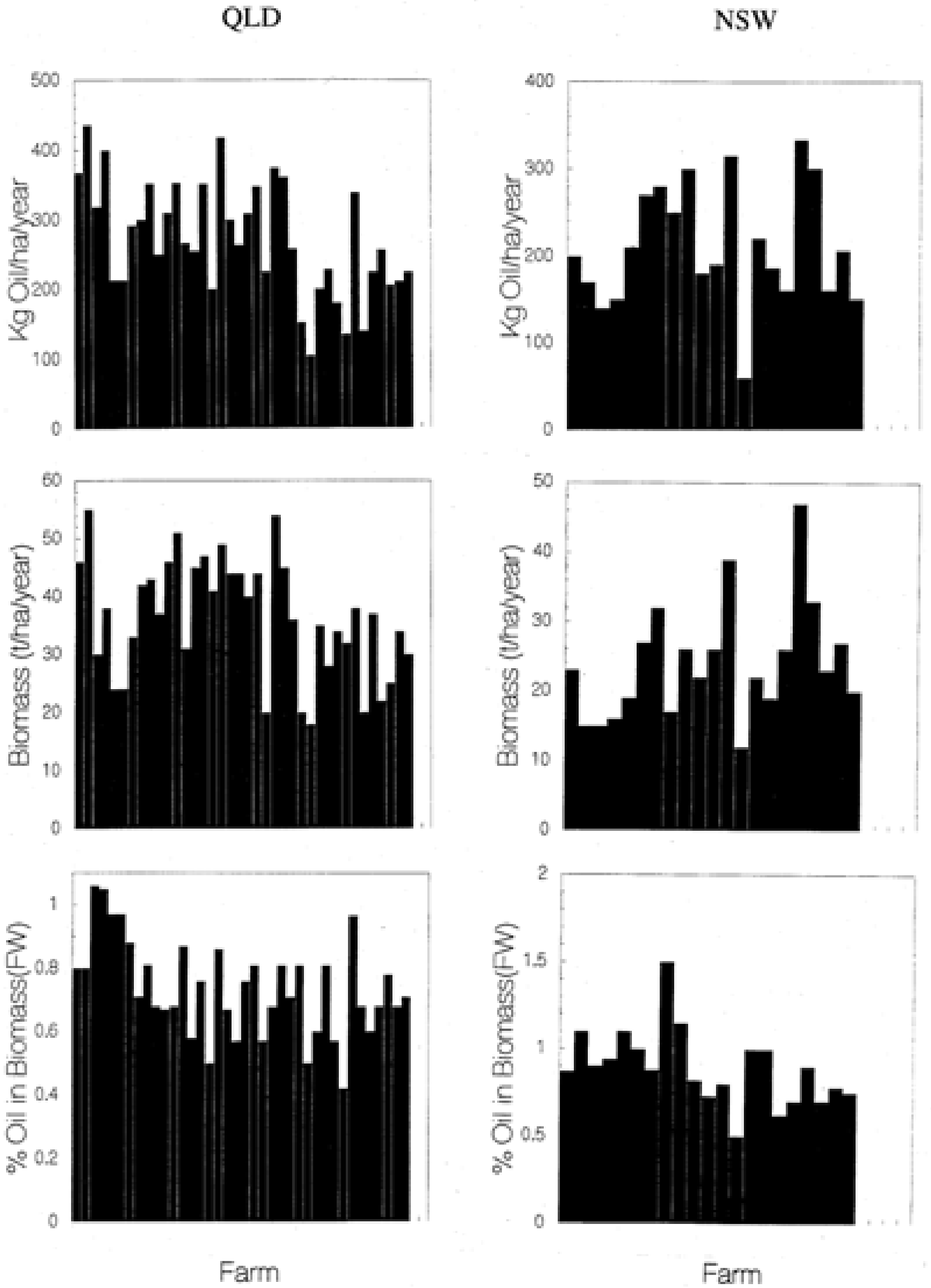


Figure 2: The oil yield, biomass yield and oil concentration in the biomass for each of the farms in the survey.

5. Discussion

5.1 Fertiliser levels and production

The results from this survey do not indicate a strong link between the levels of fertiliser applied or the number of applications and yields (biomass or oil/ha) in either QLD or NSW. There was also no strong link between the Biomass yield and oil yield and the overall fertility rating in both states (Figure 3). For the individual nutrients, there was no link between oil or biomass yields and the N, P, K or other nutrients levels (Figure 4).

In both states, there was a slight negative effect of fertility levels (overall rating, N and K levels) on the % oil in the biomass (oil concentration) (Figure 3). This indicates that increasing fertiliser use to increase biomass levels maybe having a slightly negative impact on the oil concentration in the plant or the % leaf to stem ratio. The second of the two seems more probable because with increased plant size it would be expected to see a decrease in the proportion of twig material in the harvested sample lowering the % oil on a fresh weight basis. Also, measurements of oil concentrations of individual plants indicate oil concentration increases with better nutrition.

The negative effect of increasing biomass on the % oil in Biomass can be seen more clearly in Figure 5. The link was not so obvious in QLD. This effect could also be due to differences in moisture content between samples.

The poor correlation between fertiliser inputs or fertility rating and soil production is surprising given the large amounts of nutrients that are removed at each harvest. The most likely explanation is the large number of factors involved in determining the final yield of tea tree oil and therefore it is often difficult to obtain clear trends from survey data.

Factors such as moisture availability, soil type (texture, fertility, depth and pH), plant density, variety, climate (rainfall, humidity, temperature), weeds, insects and leaf drop all have the potential to influence tea tree oil yields greatly. For example, leaf drop from disease or dry weather could reduce yields by as much as 50% even if fertiliser inputs had been optimum. Therefore, the responses to fertiliser are only likely to be observed in full when all these confounding factors are controlled. Nutritional research should therefore be conducted on just a few sites where the effects of these other factors can be minimised.

Despite the likely influence of these other factors on oil yields if regular fertilisation was required to maintain satisfactory yields some trends would have been expected even in the survey results. Therefore it could be assumed that in the early years of a plantation the tree obtains sufficient nutrients from soil reserves. While this is happening, little or no fertiliser will be required. However, eventually soil reserves will be run down and plant nutrient levels will fall reducing production.

5.2 Relationships between oil yield, biomass yield and oil concentration

Survey data indicated that there was a strong link between the oil yield/ha and the amount of biomass harvested in QLD and NSW (Figure 6). This is not surprising given the strong dependence between the two variables.

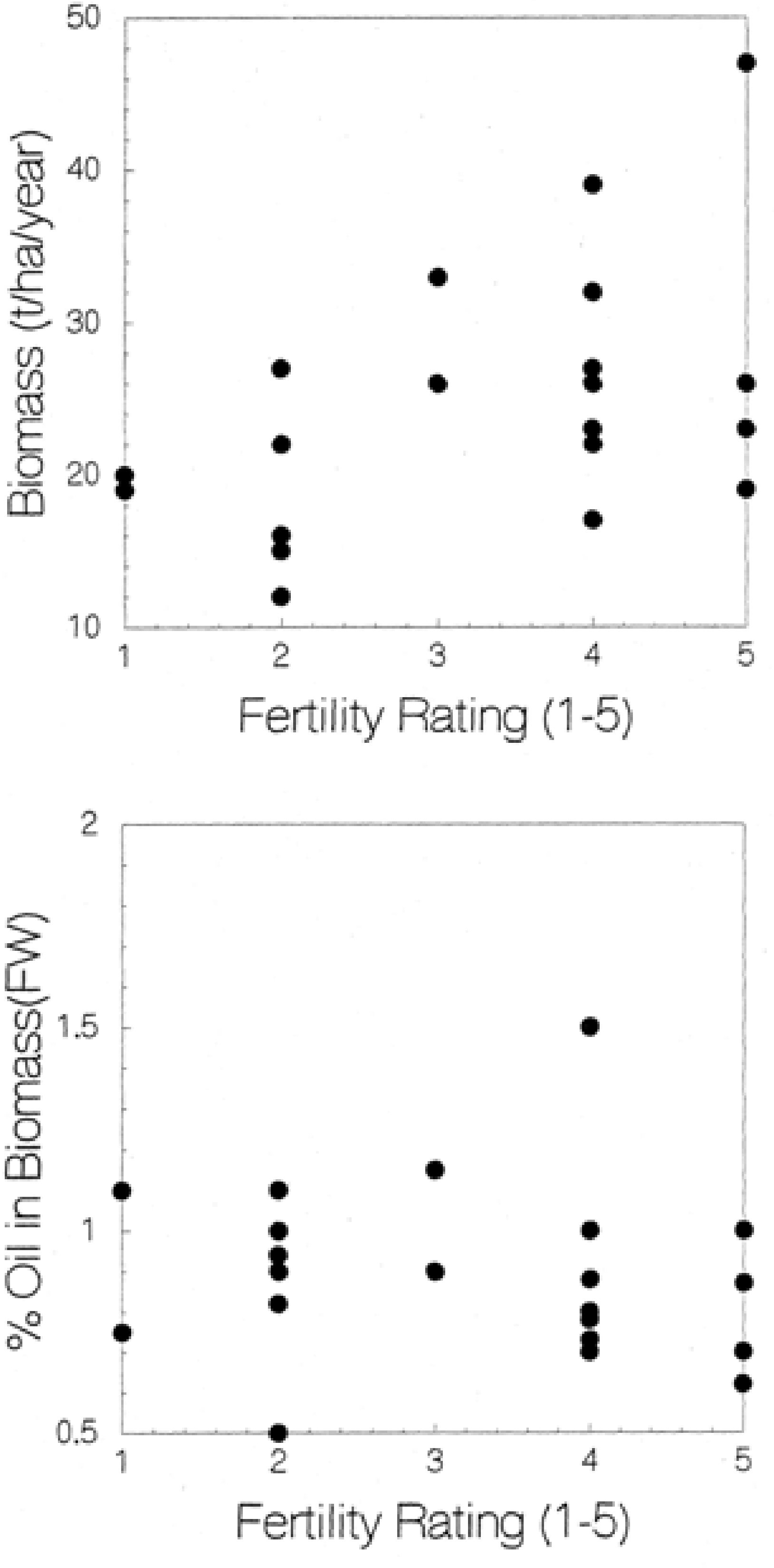


Figure 3. The effect of fertility level on biomass production and the oil concentration in the biomass in New South Wales.

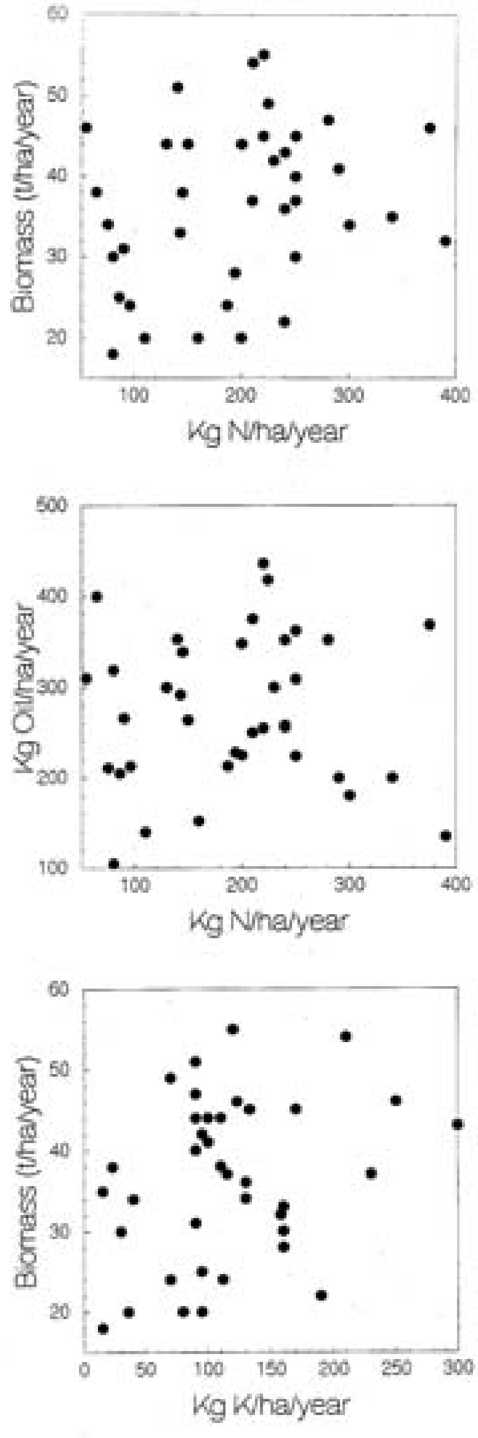


Figure 4: The effect of the level of nitrogen and potassium on the biomass and oil yield in Queensland.

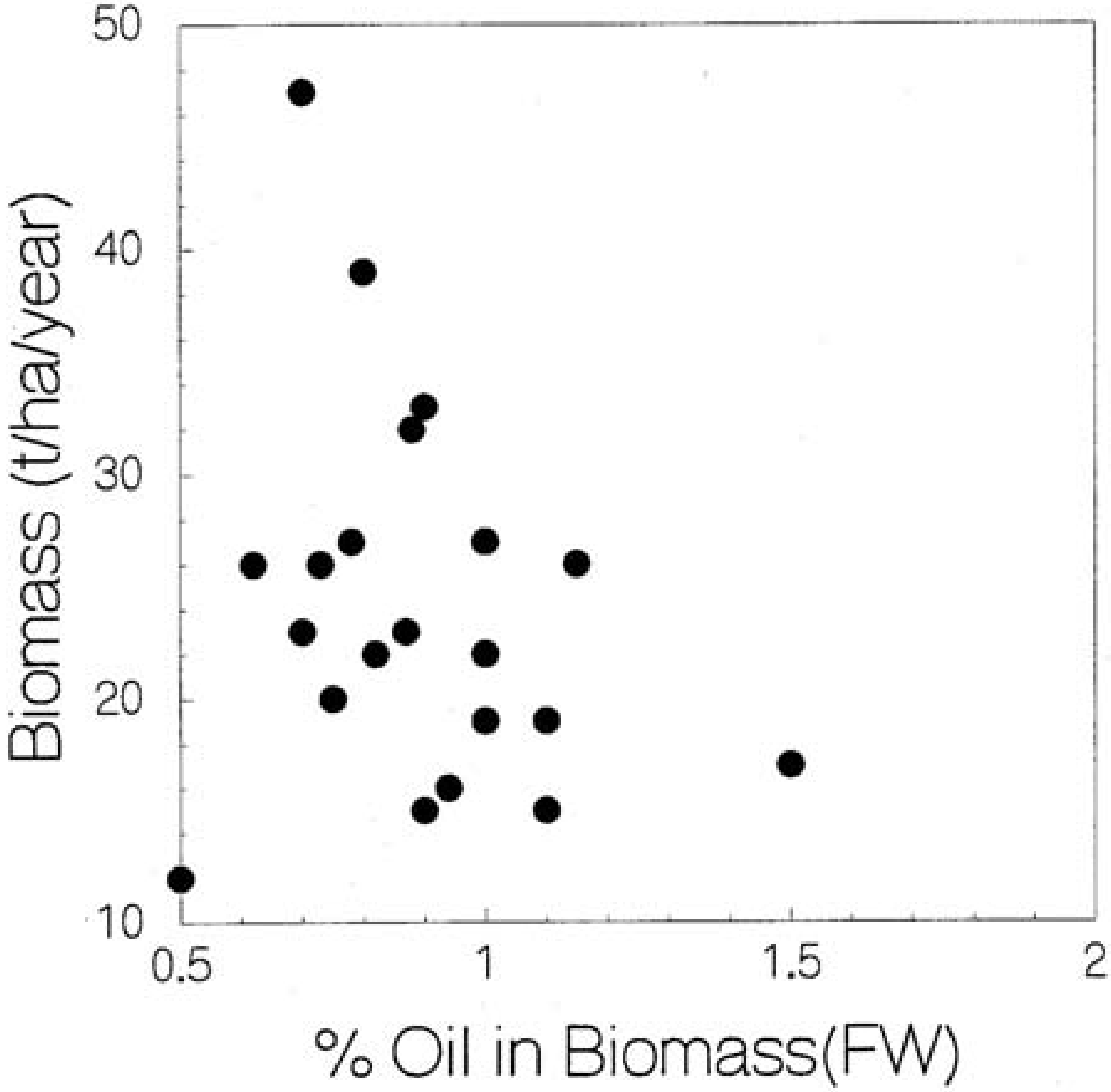
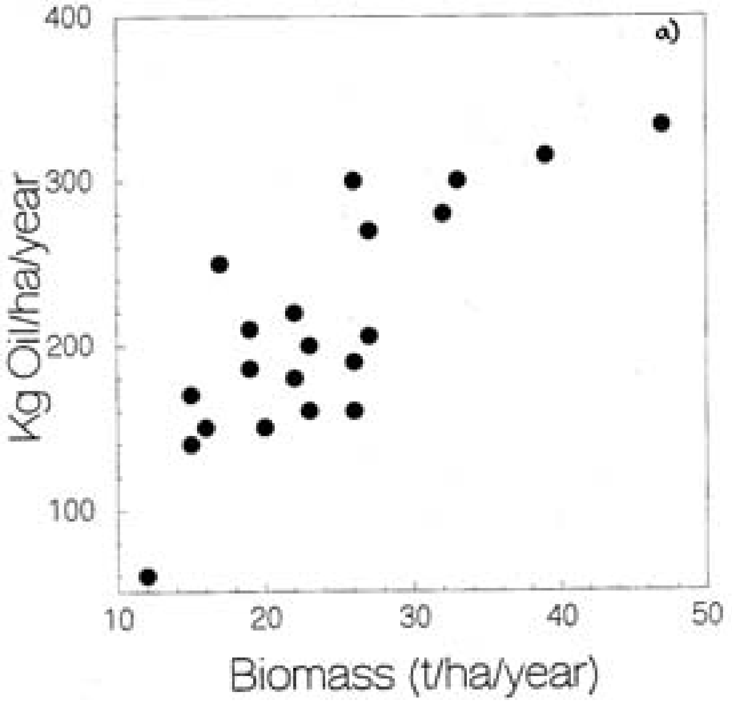


Figure 5: The relationship between the oil concentration and the biomass yield in New South Wales.



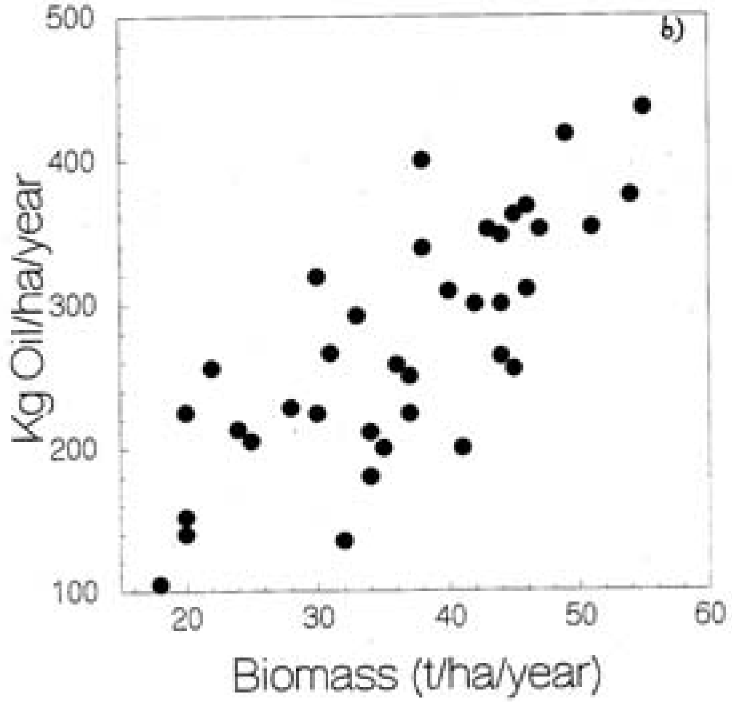


Figure 6: The relationship between biomass yield and oil yield in a) New South Wales and b) Queensland.

5.3 Critical Levels

From the leaf and soil samples taken throughout this project the following soil and leaf nutrient levels are given as a guide to optimum levels for maximum production.

LEAF		SOIL	
N (%)	1.8-2.0	pH (water)	5.5-6.5
P (%)	0.1-0.2	N nitrate (mg/kg)	30-60
K (%)	1.5	P colwell (mg/kg)	20-40
Ca (%)	0.5-0.7	K (meq/100g)	0.3-0.4
Mg (%)	0.1-0.2	Ca (meq/100g)	1-3
S (%)	0.2	S (mg/kg)	10-30
Na (%)	0.4	Mg (meq/100g)	1-2
Cl (%)	0.3	Cu (mg/kg)	2-10
Cu (mg/kg)	10-20	Zn (mg/kg)	2-15
Zn (mg/kg)	40	Fe (mg/kg)	20-50
Mn (mg/kg)	100-500	Mn (mg/kg)	20-50
Fe (mg/kg)	50-100	B (mg/kg)	0.1-0.3
B (mg/kg)	30-50		

Leaf nutrient levels seem to give the best guide to fertiliser requirements. The relationship between soil levels and crop performance doesn't seem as clear as leaf levels and crop performance. Factors such as nutrient availability and plant access to nutrients also need to be considered when looking at soil nutrient levels.

5.4 Nutrient removal

To develop a fertiliser program, a useful starting point is to calculate the amount of nutrients removed in the harvested portion of the crop. The amount of nutrients removed in tea tree is a function of the biomass yield multiplied by the nutrient level in the biomass. For a sustainable production system, the nutrients removed should at the very least be replaced. Growers who do not replace nutrients removed in the crop are rapidly depleting soil reserves. The results of declining soil fertility are slower vegetative growth, poorer root systems, yellow regrowth following harvest and death of stumps.

In the following table the amount of nutrient removed, based on an above average crop biomass yield in Qld or NSW is given.

Nutrient	Levels found in harvested biomass healthy trees	Nutrient Removed in above average crops NSW	QLD
		(based on 36 t FW/ha/year) or 14.4 t Dry Weight/year	(based on 50t FW/ha/year) or 20.0t Dry Weight/year
N%	0.9	130 kg	180.0 kg
P%	0.1	15 kg	20 kg
K%	1.1	158 kg	220 kg
Ca%	0.45	65 kg	90 kg
Mg%	0.15	22 kg	30 kg
S%	0.11	16 kg	22 kg
Cu mg/kg	10	0.15 kg	0.2 kg
Zn mg/kg	20	0.3 kg	0.4 kg
Mn mg/kg	180	2.6 kg	3.6 kg
Fe mg/kg	70	1.0 kg	1.4 kg
B mg/kg	20	0.3 kg	0.4 kg

These levels of nutrient removed would need to be adjusted for the actual biomass yield being achieved on growers properties. On top of these levels, allowances would need to be made for leaching, erosion, nutrients tied up in plants (trunk, roots), fixation to soil and volatilisation, minus mineralisation from soil and organic matter and inputs from the atmosphere.

This data indicates that tea trees use quite large amounts of nutrients especially when large amounts of biomass are harvested. So that even though tea tree is found naturally in infertile swampy soils; for good production they do require large fertiliser inputs. Tea trees require large amounts of nitrogen and potassium but little phosphorus. These nutrients should be applied in roughly the ratio 9:1:9. These results compare favourably with the results found by Bede Clarke who found that in a high yielding crop in NSW, tea trees removed 105 kg N, 21 kg of P, 126 kg of K, 26 kg of S, 36 kg of Ca and 36 kg of Mg.

Average N, P, K application rates of 53, 20 and 61 kg/ha/year in NSW and 194, 26 and 115 kg/ha/year in QLD, indicate that growers in NSW are generally applying inadequate amounts of N and especially K; and that growers in QLD are generally applying adequate levels of N and P but not enough K to adequately replace nutrients being removed at harvest.

5.5 Fertiliser application

Generally the cost of fertiliser will be quite small compared to other inputs. Having decided on the approximate levels of nutrients required by tea tree, (from the nutrient removal calculation) the way in which it is applied and the types of fertiliser (to match the plants needs) has to be considered. In many crops the ratio of N, P and K and the levels of each has to be varied throughout the cropping cycle to match the plants needs. This is complicated by such factors as flowering, fruiting, dormancy and fruit quality issues. In tea tree where the aim is to maximise vegetative growth, and there is no dormancy period, flowering or fruiting issues, the fertiliser program is very much simplified. Fertiliser inputs can be matched to the vegetative growth cycle and the size of the plants (Figure 7).

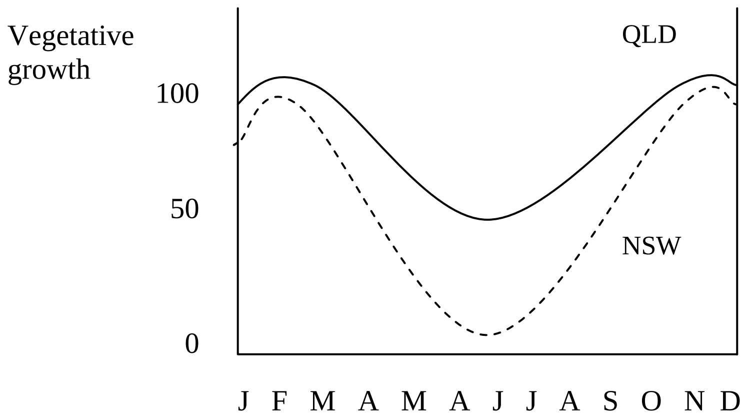


Figure 7: Tea Tree Growth Cycle

Small amounts of fertiliser (all nutrients) applied regularly during the growing season would appear best. This would be all year around in Queensland and from September to April in NSW. Based on the accumulation of biomass it is suggested that fertiliser applications be split as follows.

Months following harvest	Proportion of total nutrients
0-2	10%
2-4	20%
4-6	20%
6-harvest	50%

Because tea trees can be burnt with too much fertiliser and all nutrients are required to be available for the whole crop, regular small applications are likely to be more beneficial than a few large applications. The optimum number of applications is likely to be between four and twelve depending on the climate (rainfall pattern) and the soil type.

Slow release fertilisers are likely to be beneficial because nutrients will be available in small amounts over an extended period - also problems with leaching in sandy soil and high rainfall areas will be less of a problem.

Most fertiliser is best applied as soil dressings or through the irrigation and not as foliar sprays - as tea tree leaves are not well adapted to absorb large amounts of nutrients through the leaves. However, foliar applications of some of the micronutrients (e.g. Fe, Cu, Zn) can be beneficial to correct deficiencies. These nutrients are not required in great amounts and they are also quite immobile in the soil and plants, thus, foliar application makes good sense.

Complete fertilisers such as Nitrophoska Blue, Aftergraze, Ck77, Ck88, CN89 are likely to be useful as they contain about the right mix of N.P.K. (high N and K, low P). If using straight fertilisers urea, nitram, potassium nitrate, k-spray, potassium chloride, are also likely to be useful.

It is recommended that growers conduct two leaf nutrient tests (mid season and at harvest) and one soil nutrient test (at harvest) in order to check the results of fertiliser practices and plant nutrient removal. Growers can build up a useful record of crop responses to fertiliser by monitoring changes in leaf and soil nutrient levels over a number of seasons in relation to previous fertiliser applications.

5.6 Future nutrition studies

The greatest gains are likely to come from determining the optimum levels of nitrogen, phosphorus and potassium. This survey would suggest that fertiliser treatments should include;

	NSW			**QLD**		
N	50	100	150 kg/ha	100	150	200 kg/ha
P	10	20	30 kg/ha	15	20	30 kg/ha
K	50	125	200 kg/ha	150	200	250 kg/ha

Fertiliser needs to be applied evenly through the growing season and other constraints on growth need to be minimised.

6. Implications

This project has increased the knowledge base of the nutritional requirements of tea tree. The current nutritional status of the Australian tea tree industry has been documented. Results have indicated the amounts and types of fertiliser being used, the timing of application, the range in nutritional status, and the range in yields (biomass, oil concentration and oil yields) being achieved.

The data has indicated that many growers are not providing adequate nutrition levels to replace most nutrients being removed during harvest. Through this project growers are now more knowledgeable about the nutritional requirements of tea tree.

The optimal leaf and soil nutrient levels established provide a guide for growers to assess their fertiliser practices. Results presented allow growers to calculate the likely fertiliser requirements. This information will lead to better nutritional management resulting in improved production and reduced costs.

7. Recommendations

The survey data indicates no correlation between fertiliser inputs or fertility rating and the oil yield. This is surprising given the large amounts of nutrients that are removed at each harvest. As discussed, many other factors influence tea tree oil yields and therefore it is often difficult to obtain clear trends from survey data. Never the less, some trends would have been expected. This creates a dilemma when setting recommendations for fertiliser use.

A conservative approach and one that will apply in the long term and be sustainable is to use sufficient fertiliser to replace the nutrients removed at harvest. In QLD this would be around 180 kg N, 20 kg P and 220 kg K/ha/year and in NSW 130 kg N, 15 kg P and 15 kg K/ha/year. This should be applied regularly in small amounts throughout the growing season in approximately the following proportions.

Month from harvesting	% of total nutrients
0-2	10%
2-4	20%
4-6	20%
6-harvest	50%

An alternative is to assume that in the early years of a plantation, the trees can obtain sufficient nutrients from soil reserves (hence the lack of response). While this is happening, little or no fertiliser will be required. However it is important that the plant and soil nutrient status and yield trends be closely monitored to detect when soil reserves are running down.

There is a need to conduct field trials to evaluate different levels of N, P, and K on production. From the survey results the following table is provided as a guide to fertiliser treatments.

	NSW			QLD		
	low	**mid**	**high**	**Low**	**mid**	**high**
N	50	100	150 kg/ha	100	150	200 kg/ha
P	10	20	30 kg/ha	15	20	30 kg/ha
K	50	125	200 kg/ha	150	200	250 kg/ha

Fertiliser needs to be applied evenly throughout the growing season and other constraints on growth need to be minimised.

8. Bibliography

Whish, J.P.M. 1994. Improving tea tree oil production technology, plant selection and propagation. Uni of New England, Masters Degree, 1994.

Bolton, K.G.E. and Greenway, M. 1995. Growth characteristics and leaf phosphorous concentration of 3 melaleuca species sand cultured in different effluent concentrations. Proceedings of National Conference on wetlands for water quality control. Townsville, 1995.

List, S.E., Brown, P.H., Low, C.S. and Walsh, K.B. 1996. A micro-propagation protocol for Melaleuca alternifolia tea tree. Australian journal of Experimental Agriculture. 36, 755-760.

Franz Ch. 1983. Nutrient and water management for medicinal and aromatic plants. Acta Horticulture. 203-215.

Hornok, L. 1983. Influence of nutrition on the yield and content of active components in some essential oil plants. Acta Horticulture. 239-247.

Mahdi, M.Z. 1987. Effect of nitrogen fertiliser on growth and essential oil of Eucalyptus Torgnata and E. Angulosa. Acta Horticulture. 73-81.

Boland, D.J., Brophy, J.J. and House, A.P.N. 1991. Eucalyptus leaf oils use, chemistry, distillation and marketing. Inkata press. Sydney.

Growns. D. 1995. Waxflower for cut flower production. Farmnote 86/95. Agriculture. W.A.

Reid. A. 1992. Wildflower production - Waxflower and related species. 61/92 Agriculture. W.A.

Colton, R. B. and Murtagh, G. J. 1990. Tea Tree Oil - Plantation production. NSW Agriculture and Fisheries. Agfact p6.4.6.

Murtagh. G. J. Factors affecting the oil concentration in tea tree. NSW Agriculture.

Vomel, A. 1984. Problems and advantages of mineral fertilisation with medicinal plants. Acta Horticulture. 144.

Johns, M.R., Johns, J.E., and Rudolph. V. 1992. Steam distillation of tea tree (Melaleuca alternifolia) Oil. J. Sci Food. Agric. 58:49-53.

Weir, R.G. and Cresswell, G.C. 1995. Plant nutrition disorders. Inkata Press. Melbourne.

Grove, T. S., Thomson, B. D. and Malazcjuk. N. 1996. Nutritional physiology of Eucalyptus: uptake distribution and utilisation. In P.M. Attiwil and M. A. Adams (eds). Nutrition of Eucalyptus. CSIRO Australia. 77-108.

Reuter, D. J. and Robinson, J. B. (eds) 1986. Plant analysis. Inkata Press. Melbourne.

Judd, T. S., Attiwil, P. M. and Adams, M. A. 1996. Nutrient concentrations in Eucalyptus: a synthesis in relation to differences between taxa, sites and components. In P. M. Attiwil and M. A. Adams (eds). Nutrition of Eucalyptus. CSIRO Australia. 123-153.

9. Appendices

9.1 Survey

Name: ____

Location: ____

The information for this survey needs to come from blocks of tea trees, which have been harvested at least a few times.

1. Fertiliser Use

- Types of fertiliser used e.g. Urea, Q5, nitrofosca, foliar fertiliser
- Amount of fertiliser used e.g. 2 bags/Ac, 100 kg/ha (or range over last few years or average)

- How often e.g. once/crop, once/month
- Time of year applied e.g. summer, winter

---

2. Have you had any leaf or soil analysis done?

If so can I have a copy (I'll post them straight back to you)

---

3. Level of management (Circle)

High		Medium		Low
1	2	3	4	5

---

4. Soil (Circle)

Soil fertility -

High		Medium		Low
1	2	3	4	5

Soil type if known e.g. peat, clay, alluvial
Soil depth

5. Irrigation

Do you irrigate?
How much e.g. 1”/week, 10ML/ha
Do trees have access to water at depth

6. Weeds

Have weeds reduced yields?

7. Insects

Have insects reduced yields?

8. Yields

Total weight of plant material harvested e.g. pots/Ac, kg/ha

Oil yields e.g. Kg/pot, l/pot, Kg/ha

9. Harvest Information

Age of trees at harvest e.g. 6-12 months
Size of trees e.g. 2 m tall

Any leaf drop e.g. 20%
Plant density e.g. 30 000/ha or 1m x 30cm

9.2 Survey Results - QLD

Farm	Kg of N/ha applied	Kg of P/ha applied	Kg of k/ha applied	Kg of Ca/ha applied	Kg of Mg/ha applied	Kg of S/ha applied	Other nutrients applied	Number of applications/ crop	Overall fertility rating (1-5)	Biomass tonnes/ha/12 months	% oil in biomass on FW basis	Yield kg oil/ha/12 months
1	375	40	250	15	15	50	Cu Zn Fe	6	5	46	0.8	368
2	220	30	120	40	✓	24	Zn foliar	26	4	55	0.8	436
3	80	5	30	50	✓	35	-	3	2	30	1.06	319
4	64	4	23	-	-	4	-	4	1	38	1.05	400
5	187	25	70	-	-	4	Fe Cu Zn	5	3	24	0.97	213
6	96	40	112	-	-	4	Fe Cu Zn	5	3	24	0.97	213
7	143	27	160	50	✓	27	Fe Mn B	4	4	33	0.88	292
8	230	25	95	9	✓	90	Cu Zn	3	4	42	0.71	300
9	240	10	300	40	✓	40	Fe Cu Zn	2	5	43	0.81	352
10	210	13	230	13	-	13	Foliar	2	5	37	0.68	250
11	54	60	123	10	-	54	-	6	2	46	0.67	310
12	140	65	90	50	✓	90	-	2	3	51	0.68	353
13	90	20	90	60	✓	90	-	2	2.5	31	0.87	266
14	220	20	133	40	✓	50	-	3	3.5	45	0.58	255
15	280	20	90	40	✓	50	Foliar	3	4	47	0.76	353
16	290	30	100	50	✓	50	Foliar	4	4	41	0.58	200
17	224	15	70	4	-	1	Fe Zn	6	4	49	0.86	418
18	130	30	90	6	-	30	Fe Zn Cu	6	3	44	0.67	300
19	150	30	110	10	-	30	-	6	3	44	0.57	264
20	250	20	90	30	✓	7	-	3	3	40	0.76	309
21	200	20	100	20	✓	7	-	3	4	44	0.81	345
22	200	23	95	30	✓	7	Foliar	3	4	20	0.57	225
23	210	20	210	20	✓	100	Fe Zn Cu	6	5	54	0.68	375
24	250	55	170	50	20	80	Fe Zn Cu	8	5	45	0.81	362
25	240	20	130	50	✓	✓	-	8	4	36	0.71	258
26	160	6	36	-	-	7	-	3	3	19.6	0.81	152
27	80	5	15	-	-	-	-	2	2	18	0.5	105
28	340	5	15	-	-	-	-	3	3	35	0.6	200
29	194	110	160	20	✓	✓	-	4	4	28	0.81	228
30	300	5	130	-	-	-	-	4	4	34	0.57	180
31	390	40	158	10	✓	✓	Foliar	3	5	32	0.42	135
32	145	30	110	50	✓	✓	Foliar	3	4	38	0.96	338

33	110	20	80	50	✓	✓	Fe Cu Zn foliar	3	3	20	0.68	140
34	250	22	115	60	✓	✓	Foliar	6	4	37	0.6	224
35	240	20	190	50	✓	✓	Foliar	7	5	22	0.68	256
36	86	30	95	10	✓	✓	Foliar	3	3	25	0.78	205
37	75	20	40	15	✓	✓	Foliar	3	2	34	0.68	211
38	250	25	160	40	✓	✓	Foliar	3	5	30	0.71	224
Average	194	26	115							36.4	0.738	272

✓ - Small amounts applied (5-15 kg) as a component in mixed fertilisers.

9.3 Survey Results - NSW

Farm	Kg of N/ha applied	Kg of P/ha applied	Kg of k/ha applied	Other nutrients applied rating(1-5)	Number of app./crop	Overall fertility rating (1-5)	Biomass tonnes/ha/ 12 months	% oil in biomass on FW basis	Yield kg oil/ha/12 months
1	100	40	140	1	2	5	23	0.87	200
2	20	5	20	1	1	2	15	1.1	170
3	20	5	20	1	1	2	15	0.9	140
4	22	4	22	1	1	2	16	0.94	150
5	7	7	7	2	1	1	19	1.1	210
6	10	5	10	3	1	2	27	1.0	270
7	150	0	150	1	3	4	32	0.88	280
8	68	72	100	2	2	4	17	1.5	250
9	35	7	75	3	2	3	26	1.15	300
10	2	2	2	1	1	2	22	0.82	180
11	52	10	65	3	3	4	26	0.73	190
12	55	18	60	4	3	4	39	0.81	315
13	0	20	38	3	1	2	12	0.5	60
14	30	12	75	3	2	4	22	1.0	220
15	120	50	100	3	3	5	19	1.0	186
16	130	50	100	2	3	5	26	0.62	160
17	150	50	150	2	3	5	47	0.70	333
18	25	10	25	1	1	3	33	0.9	300
19	100	50	100	3	2	4	23	0.7	160
20	20	5	20	3	1	4	27	0.78	206
21	0	0	0	1	1	1	20	0.75	150
Average	53	20	61				24.1	0.89	210