INVESTIGATION INTO THE EFFECTS OF FAST-GROWING TREE CROPS ON SITE IN KARNATAKA

Short title:
FAST-GROWING TREE PROJECT

Report No. 45
Following a field visit
May 1990

by

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SUMMARY

This brief visit was designed to be an introduction and familiarisation excercise for Drs Lines and Harrison who have recently become involved with the project. Dr Harrison assessed various laboratory sites for their suitability to carry out a particular root bioassay technique involving radio isotopes. Dr Harrison's report is included as a separate section. Dr Lines was mostly concerned with visiting the field experiments and meeting the personnel involved in running the project. Dr Dury was involved with assembling data and assisting with any other outstanding matters.

ABBREVIATIONS

FGTP	Fast-growing tree project
IAEA	International Atomic Energy Agency
IH	Institute of Hydrology
ISRO	Indian Space Research Organisation
ITE	Institute of Terrestial Ecology
KFD	Karnataka State Forest Department
MPM	Mysore Paper Mills Ltd.
ODA	Overseas Development Administration, London
OFI	Oxford Forestry Institute
UAS	University of Agricultural Sciences, Bangalore

CONTENTS

1. OBJECTIVES

The objectives of the visit were (1) to introduce Dr Harrison and Dr Lines to the Indian project staff and to famaliarise them with the work in progress, (2) review progress on plot assessments and collect any outstanding data for analysis, and (3) enable Dr Harrison to make recommendations for future involvement in the research programme.

2. VISIT BY THE ODA MINISTER

The Minister for Overseas Development, Mrs. Lynda Chalker, MP, visited Bangalore on 4 May. A press conference at the Bangalore Club was widely reported in the following days newspapers. Here is an extract from the Press Statement:

"I am sorry that because of my very brief time in your beautiful garden city I was not able to visit the two major forestry projects we have been supporting in Karnataka since 1984. These are of course the well-known Karnataka Social Forestry Project ... and the Mysore Paper Mills Forestry Project."

"Related to but separate from both these projects is an investigation, supported by us and carried out jointly by the Karnataka Forest Department and MPM Ltd, into the effects which short rotation tree species, such as eucalyptus, have on the soils and hydrology of the sites on which they are planted. The results of this important research ... should provide for an informed assessment of the environmental effects of fast-growing trees."

"Our consultants have discussed with both KFD and MPM the possibility of our providing continued support in research. The environmental aspects of tree plantations, possibly including influences on mesoclimate, are expected to be a major subject of any future research project, which would also probably embrace tree breeding and plantation silviculture."

3. PROJECT SEMINAR

Mr Javeed Mumtaz obtained a very reasonable quote from the Hotel Ashok for the hosting of the seminar, as a result of which Mr Swaminath has provisionally booked two halls and ten rooms from 5th to 7th of Feb 1991. The conference package consists of a lunch with mid-morning and mid-afternoon tea/coffee. Mr Yellappa Reddy has indicated that there is a possibility of obtaining sponsorship for the evening dinners.

An advertisement for the seminar appeared in the March edition of Myforest. Mr Swaminath is getting a good response from potential participants. ODA have been requested to provide funding for overseas speakers, to ensure an 'international' conference. On return to Oxford, SJD lectured to a party of Indian agroforesters from agricultural universities who expressed an interest in attending the seminar.

The seminar planning has received a boost with the news that Dr M S Swaminathan, president of the World Wide Fund for Nature - India, will give the inaugural address.

4. PERMANENT SAMPLE PLOTS

4.1 KFD

Further data were received, in particular from a number of newly laid out plots. The amended plot register is given in Appendix 3. Since the farmers' application of fertilizers was variable over different areas, and this may have a major bearing on growth rates, the need to record such information was stressed. The information to be recorded includes:

- fertilizer
  - what type ?
  - how much ?
  - when applied ?
- Irrigation ?
- Soil conservation
  - trenching ?
  - bunds ?
- Topography ?
- Insecticides used ?
- Fungicides used ?
- Termite damage ?

This information should be recorded for all subsequent plots, and should be collected for all plots where measurements have already been made.

4.2 MPM

Summary sample plot data for *Pinus caribaea* and *Casuarina equisetifolia* are presented in Appendix 4. This was not included in SJD's last Tour Report (No. 41). Since the volume functions have yet to be determined, it should be borne in mind that these tables are only very rough approximations. Following a suggestion made by Mr. Kariyappa, the method for calculating volume for *Acacia auriculiformis* is being re-examined; it is predicted that this will lead to higher estimates of volume (cubic metres per hectare).

The total area of plantations raised by MPM from 1981 to 1989 is shown in Table 1. The area planted under acacia is 3543 ha in Thirthahalli and 4830 ha in Sagar, and the area planted under eucalypts is 3204 ha in Shimoga and 4027 ha in Bhadravathi. There is thus a shortage of P1 plots in the acacia plantations (only 4 plots), as compared to the 48 plots in the eucalypt plantations.

To remedy this situation, it is recommended that at least 15 extra P1 plots are located in each of the *Pinus*, *Casuarina* and *Acacia* plantations this year.

TABLE 1 ABSTRACT OF PLANTATIONS RAISED BY MPM FROM 1981 TO 1989

(IN HA.)

YEAR	WET ZONE								DRY ZONE		GRAND TOTAL
	THIRTHAHALLI DVN.				SAGAR DVN.				SHIMOGA DVN.	BHADRAVATHI DVN	
	Cas.	Aca.	Pin.	Total	Cas.	Aca.	Pin.	Total	Total (Euc.)	Total (Euc.)	
1981	-	32	-	32	-	-	-	-	83	113	228
1982	100	262	-	362	-	-	-	-	202	357	921
1983	47	304	10	361	92	200	-	292	327	378	1358
1984	70	456	-	526	107	480	9	596	403	431	1956
1985	129	469	19	617	185	560	25	770	651	605	2643
1986	357	341	25	923	124	769	45	938	742	807	3410
1987	193	631	-	824	183	729	-	912	239	625	2600
1988	-	296	328	624	-	296	327	923	336	278	1861
1989	-	552	9	561	-	608	2	610	221	433	1825
	896	3543	391	4830	691	3642	408	4741	3204	4027	16802

4.3 SITE DATA

The importance of collecting site data was emphasised in Tour Report No. 41. Two sets of the necessary equipment have now been purchased and are presently being stored at the KFD research site at Hosakote; the MPM equipment is to be forwarded post haste. The two Munsell colour charts arrived in Oxford at the time of the visit, and these will either be carried out or given to Mr. Swaminath/Mr. Kariyappa to take back to India.

5. EXPERIMENTAL PLOTS

The maintenance of these plots continues to be of a high quality. The experimental plot register is given in Appendix 5. Messrs. Khan, Mokther and Satish are requested to fill up the gaps (denoted by *), if necessary by reminding field staff to release the relevant data. This should be completed before October 1990, when Adlard/Dury return to Karnataka. The list of experiments for which there is incomplete data on the computer is as follows:

Experiment No.	Title	Location
01	Tree and annual crop interaction (ragi)	Devabal
01	Tree and annual crop interaction (ragi)	Kalankatte
02	Tree with tree mixture	Devabal
02	Tree with tree mixture	Nanjapura
03	Clinal spacing (ragi)	Devabal
04	Thinning E.camaldulensis	Devabal
09	Pine spacing	Varkodu
10	Fertilizer trial E.camaldulensis	Devabal
01	Tree and annual crop interaction	Hoskote
02	Tree with tree mixture	Hoskote
03	Clinal spacing	Hoskote

The tree and annual crop experiment at Hosakote has not fared too well. All but three eucalypts have suffered from termite attack. All but two Casuarina have been replanted, and all the Leucaena have died. Only the Acacias have prospered.

ODNRI, Chatham have completed the foliar analyses from Hoskote (comparative nutrient studies experiment) and the soil analyses are awaited. It is suggested that the next batch are analysed at U.A.S., and a small sample (say, 5%) be sent to ODNRI for calibration.

Inspection of the fertilizer experiments has posed many questions (see Dr Harrisons report). It was feared from initial analysis of the data that highly significant differences between treatments at the time of planting would complicate the analysis from further measurements. However analysis of the data at OFI has revealed an error in the original calculations, resulting in an increased sum of squares for the N*P*K interaction, and consequently a reduced error sum of squares. This resulted in inflated F ratios, and hence the many significant differences encountered. Re-calculation has shown that the only significant differences at time of planting were for experiments 11ATH (*Pinus tecunumanii*, Varkodu - block difference) and 114TH (*Pinus tecunumanii*, Halvani - N*P*K interaction difference). These may be accounted for by using analysis of covariance. The analyses to date have shown various treatment effects, but sometimes negative ie. increased growth with reduced levels of treatment. Thus careful interpretation is required.

6. DESTRUCTIVE SAMPLE PLOTS

Six D plots have been completed by MPM. These are:

	DISTRICT	TALUK	SPECIES	PLANTING YEAR
1.	Thirthahalli	Aralapur	Acacia	1983
2.	Bhadravathi	Thamadahalli	Eucalyptus	1984
3.	Shimoga	Haramagatta	Eucalyptus	1984
4.	Shimoga	Haramagatta	Eucalyptus	1983
5.	Shimoga	Devebal	Eucalyptus	1984
6.	Shimoga	Devebal	Eucalyptus	1983

It was recommended that after the monsoon at least 5 more D plots are completed for Acacia and 5 for Eucalyptus. The lay-out for recording the data on computer (on the Supercalc spreadsheet) is shown in Appendix 6. This is the recommended lay-out for both the MPM and KFD data. The dry weights (KFD) and volume data (MPM and KFD) should be updated as soon as possible - this has yet to be put onto computer.

7. TEMPORARY SAMPLE PLOTS

The input of data for the 1986 plantations was not quite completed during the visit and the complete set of data is still awaited. Mr. Kariyappa is requested to bring this with him to the UK. A copy of the results is to be sent to Mr. Peter Massey of CDC.

8. FINANCE

The three computer operators salaries have been upgraded as follows: R.Khan and Mokther Ahmed Rps.1600 per month; Satish Rps.1500 per month. Permission has been given for Khan to attend a 10 day computer programming course (at no extra expense to ODA) starting 10th. June.

Because of increased costs at Shimoga, Rps.6000 will be paid monthly from the Bangalore bank account to Jagadeesh instead of Rps.5000. The monthly accounts from MPM are being received at OFI with very little delay.

A 'topping up' sum of £6000 has been sent to the bank account in Bangalore. Mr. Swaminath is requested to bring any outstanding receipts on his forthcoming trip to the UK.

APPENDIX 1

ITINERARY

2 May	Arrive Bangalore 18.30 via Bombay.
3 May	Discussions with Mr Swaminath and other KFD staff, IRC and JR (IH), Prof. Udaya Kumar and Dr R Umashankar (UAS). Visit MPM to meet PR officer. Meet P. Rosier IH. SD computing with R. Khan.
4 May	Visit Hosakote experimental trials with Dr Prakash. Visit two farm plots. Meet with some of the Western Ghats mission, evening.
5 May	Meeting with Sri K.K Misra MPM. Report writing.
6 May	Travel to Shimoga check in Jewel Rock. Meet with I.Calder
7 May	Discussions with MPM officials including Mr Karyappa and Mr Bulgannawar. Visit quality testing laboratory at the paper mill, Bhadravati.
8 May	Visit Purdahl field site. SD computing in office. AFH & CEML report writing and discussions with MPM staff
9 May	Visit Devabal field site. SD computing in office. AFH & CEML report writing and discussions with MPM staff
10 May	Visit Behalli, Sagar and Thirthahalli districts
11 May	SD and AFH computing, and discussions in office. CEML ill
12 May	Travel to Bangalore day train check in Windsor Manor
13 May	Rest day
14 May	Discussions with Prof Kumar of UAS. Meet Claire Wood ODA
15 May	SD visit ISRO and D.Palin of Western Ghats mission Return flight to UK via Bombay
16 May	Arrive Heathrow

APPENDIX 2

PERSONS MET

Sri K.K. Misra, Chairman and Managing Director, MPM Ltd.
Sri G.N. Bulgannawar, Director (Forests), MPM Ltd.
Sri Annaji Rao, Conservator of Forests, MPM Ltd.
Sri Yellappa Reddy, Conservator of Forests, KFD.
Prof. Uday Kumar, UAS, Bangalore.
Dr R. Umashankar, UAS, Bangalore.
Dr V. Bhaskar, UAS, Bangalore.
Dr Swami Rao, UAS, Bangalore.
Sri B.K. Ranganath, Research Officer, ISRO, Bangalore.

APPENDIX 3 - Register of KFD Permanent Sample Plots

PSP CONTROL CHART * entered to file ; $ summarized; // completed;

ASSESSMENT DATES

Digits: 1 1 1 1 1 1 1 1

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PSP CONTROL CHART

NEW CODE Digits: 1 1 1 1 1 1 1 1

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APPENDIX 4 - Register of MPM Permanent Sample Plots

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M 1 0 1 0 2 1 2| 1985|    .      |    .    .    .        |    .  *  .   .   *|     .   *.   .        |     .$   .   .         |
M 1 0 1 0 3 1 3| 1982|    .      |    .    .    .        |    .*     .   .   *|     .   *.   .        |  *  .$   .   .         |
M 1 0 1 0 3 1 4| 1982|    .      |    .    .    .        |    .*     .   .   *|     .   *.   .        |  *  .$   .   .         |
M 1 0 1 0 3 1 5| 1982|    .      |    .    .    .        |    .*     .   .   *|     .   *.   .        |  *  .$   .   .         |
M 1 0 1 0 3 1 6| 1982|    .      |    .    .    .        |    .   *.   .   *|     .   *.   .        |  *  .$   .   .         |
M 1 0 1 0 3 1 7| 1982|    .      |    .    .    .        |    .   *.   .   *|.    .  *  .   .        |  *  .$   .   .         |
M 1 0 1 0 3 1 8| 1982|    .      |    .    .    .        |    .   *.   .   *|     .   *.   .        |  *  .$   .   .         |
M 1 0 1 0 3 1 9| 1984|    .      |    .    .    .        |    .   *.   .   *|     .   *.   .        |  *  .$   .   .         |
M 1 0 1 0 3 2 0| 1984|    .      |    .    .    .        |    .   *.   .   *|     .   *.   .        |  *  .$   .   .         |
M 1 0 1 0 4 2 1| 1983|    .      |    .    .    .        |    .   *.   .   *|     .   *.   .        |  *  .$   .   .         |
M 1 0 1 0 4 2 2| 1982|    .      |    .    .    .        |    .   *.   .   *|     .   *.   .        |  *  .$   .   .         |
M 1 0 1 0 5 2 3| 1984|    .      |    .    .    .        |    .   *.   .   *|     .   *.   .        |  *  .$   .   .         |
M 1 0 1 0 5 2 4| 1984|    .      |    .    .    .        |    .   *.   .   *|     .   *.   .        |  *  .$   .   .         |
M 1 0 2 0 1 0 1| 1984|    .      |    .    .    .        |    .   *.   .   *|     .   *.   .        |*    .$   .   .         |
M 1 0 2 0 1 0 2| 1984|    .      |    .    .    .        |    .   *.   .   *|     .   *.   .        |*    .$   .   .         |
M 1 0 2 0 1 0 3| 1984|    .      |    .    .    .        |    .   *.   .   *|     .   *.   .        |*    .$   .   .         |
```

```
PSP CONTROL CHART       * entered to file ; $ summarized; // completed;
------------------------------------------------------------------------------------------------------------
                               ASSESSMENT DATES                                                            |
NEW CODE        P.YR |1986        |1987                  |1988                    |1989                    |1990                    |
Digits:        |     |J|A|S|O|N|D|J|F|M|A|M|J|J|A|S|O|N|D|J|F|M|A|M|J|J|A|S|O|N|D|J|F|M|A|M|J|J|A|S|O|N|D|J|F|M|A|M|J|J|A|S|O|N|D|
 1 1 1 1 1 1 1|      |           |                      |                        |                        |                        |
-----------------------------------------------------------------------------------------------------------|
M 1 0 2 0 2 1 3|  1983|    .     |    .    .    .    |    .    *.    .    *|    .    *.    .    |*    .$    .    .    |
M 1 0 2 0 2 1 4|  1983|    .     |    .    .    .    |    .    *.    .    *|    .    *.    .    |*    .$    .    .    |
M 1 0 2 0 2 1 5|  1983|    .     |    .    .    .    |    .    *.    .    *|    .    *.    .    |*    .$    .    .    |
M 1 0 2 0 2 1 6|  1983|    .     |    .    .    .    |    .    *.    .    *|    .    *.    .    |*    .$    .    .    |
M 1 0 2 0 2 1 7|  1984|    .     |    .    .    .    |    .    *.    .    *|    .    *.    .    |*    .$    .    .    |
M 1 0 2 0 2 1 9|  1985|    .     |    .    .    .    |    .    *.    .    *|    .    *.    .    |*    .$    .    .    |
M 1 0 2 0 2 2 0|  1983|    .     |    .    .    .    |    .    *.    .    *|    .    *.    .    |*    .$    .    .    |
M 1 0 2 0 2 2 1|  1984|    .     |    .    .    .    |    .    *.    .    *|    .    *.    .    |*    .$    .    .    |
M 1 0 2 0 2 2 2|  1985|    .     |    .    .    .    |    .     .    .     |    .    *.    .    |*    .$    .    .    |
M 1 0 2 0 3 2 8|  1985|    .     |    .    .    .    |    .    *.    .    *|    .    *.    .    |*    .$    .    .    |
M 1 0 2 0 3 2 3|  1985|    .     |    .    .    .    |    .    *.    .    *|    .    *.    .    |*    .$    .    .    |
M 1 0 2 0 3 2 4|  1985|    .     |    .    .    .    |    .    *.    .    *|    .    *.    .    |*    .$    .    .    |
M 1 0 3 0 1 0 2|  1985|    .     |    .    .    .    |    .    *.    .    *|    .    *.    .    |*    .$    .    .    |
M 1 0 3 0 1 0 5|  1985|    .     |    .    .    .    |    .    *.    .    *|    .    *.    .    |*    .$    .    .    |
M 1 0 3 0 2 0 3|  1985|    .     |    .    .    .    |    .    *.    .    *|    .    *.    .    |     .$    .    .    |
M 1 0 3 0 3 0 7|  1984|    .     |    .    .    .    |    .    *.    .    *|    .    *.    .    |     .$    .    .    |
M 1 0 3 0 4 0 4|  1985|    .     |    .    .    .    |    .    *.    .    *|    .    *.    .    |     .$    .    .    |
M 1 0 3 0 5 0 1|  1984|    .     |    .    .    .    |    .    *.    .    *|    .    *.    .    |     .$    .    .    |
M 1 0 3 0 6 0 6|  1985|    .     |    .    .    .    |    .    *.    .    *|    .    *.    .    |     .$    .    .    |
M 1 0 4 0 1 0 1|  1983|    .     |    .    .    .    |    .    *.    .    *|    .    *.    .    |*    .$    .    .    |
M 1 0 4 0 2 0 5|  1983|    .     |    .    .    .    |    .    *.    .    *|    .    *.    .    |*    .$    .    .    |
M 1 0 4 0 3 0 4|  1983|    .     |    .    .    .    |    .    *.    .    *|    .    *.    .    |*    .$    .    .    |
M 1 0 4 0 4 0 3|  1983|    .     |    .    .    .    |    .    *.    .    *|    .    *.    .    |*    .$    .    .    |
M 1 0 4 0 5 0 2|  1982|    .     |    .    .    .    |    .    *.    .    *|    .    *.    .    |*    .$    .    .    |
M 1 0 7 0 2 0 3|      |    .     |    .    .    .    |    .    *.    .    *|    .    .*    .    |*    .$    .    .    |
M 1 0 7 0 3 0 7|      |    .     |    .    .    .    |    .    *.    .    *|    .    .*    .    |*    .$    .    .    |
M 1 0 7 0 4 0 4|      |    .     |    .    .    .    |    .    *.    .    *|    .    .*    .    |*    .$    .    .    |
M 1 0 7 0 5 0 1|      |    .     |    .    .    .    |    .    *.    .    *|    .    .*    .    |*    .$    .    .    |
M 1 0 7 0 6 0 6|      |    .     |    .    .    .    |    .    *.    .    *|    .    .*    .    |*    .$    .    .    |
```

APPENDIX 5

EXPERIMENT REGISTER * assessed; + entered to file; @ analysed; $ summarized; x completed;

ASSESSMENT DATES

NEW CODE Digits: - 2 1 1 1

NEW CODE	P.YR	1986 J	A	S	O	N	D	1987 J	F	M	A	M	J	J	A	S	O	N	D
KFD:																			
E 0 1 1 S H	1987																		
E 0 1 1 R g																			
E 0 1 1 R s																			
E 0 2 1 S H	1987																		
E 0 3 1 S H	1987																		
E 0 7 1 S H	1987																		
MPM:																			
E 0 1 2 S H	1987															+			+
E 0 1 2 S D																			
E 0 1 2 R																			
E 0 1 7 S H	1987														+			+	
E 0 1 7 S D																			
E 0 1 7 R																		*	
E 0 2 2 S H	1987																		*
E 0 2 5 S H	1987														*			*	
E 0 3 2 L H	1986		+									+							
E 0 3 2 L D																			
E 0 3 2 R						*												*	

NEW CODE	1988 J	F	M	A	M	J	J	A	S	O	N	D
KFD:												
E 0 1 1 S H												
E 0 1 1 R g		*										
E 0 1 1 R s		*										
E 0 2 1 S H									*			
E 0 3 1 S H										+		
E 0 7 1 S H							+				+	
MPM:												
E 0 1 2 S H					+							
E 0 1 2 S D												
E 0 1 2 R											*	
E 0 1 7 S H										+		
E 0 1 7 S D												
E 0 1 7 R											*	
E 0 2 2 S H					*							
E 0 2 5 S H					*							
E 0 3 2 L H					+							
E 0 3 2 L D												
E 0 3 2 R											*	

NEW CODE	1989 J	F	M	A	M	J	J	A	S	O	N	D
KFD:												
E 0 1 1 S H						*						
E 0 1 1 R g	*											*
E 0 1 1 R s	*											*
E 0 2 1 S H					+							+
E 0 3 1 S H						*						
E 0 7 1 S H				+								+
MPM:												
E 0 1 2 S H						+				+		
E 0 1 2 S D										+		
E 0 1 2 R											*	
E 0 1 7 S H											+	
E 0 1 7 S D											+	
E 0 1 7 R											*	
E 0 2 2 S H					+							
E 0 2 5 S H					*							
E 0 3 2 L H					+							
E 0 3 2 L D					+							
E 0 3 2 R											*	

NEW CODE	1990 J	F	M	A	M	J	J	A	S	O	N	D
KFD:												
E 0 1 1 S H												
E 0 1 1 R g												
E 0 1 1 R s												
E 0 2 1 S H												
E 0 3 1 S H	*											
E 0 7 1 S H												
MPM:												
E 0 1 2 S H												
E 0 1 2 S D												
E 0 1 2 R												
E 0 1 7 S H												
E 0 1 7 S D												
E 0 1 7 R												
E 0 2 2 S H												
E 0 2 5 S H	*											
E 0 3 2 L H												
E 0 3 2 L D												
E 0 3 2 R												

EXPERIMENT REGISTER * assessed; + entered to file; @ analysed; $ summarized; x completed;

ASSESSMENT DATES

NEW CODE Digits: - 2 1 1 1 1 1 1

NEW CODE	P.YR 1987	1986 J	A	S	O	N	D	1987 J	F	M	A	M	J	J	A	S	O	N	D
E 0 4 2 L H	1983													+					
E 0 5 3 H H	1982					+						+							
E 0 7 2 S H	1989																		
E 0 8 8 H H	1982																	+	
E 0 9 4 T H	1988																		
E 1 0 2 L H	1988																		
E 1 0 7 L H	1988																		
E 1 1 4 P H	1988																		
E 1 1 4 T H	1988																		
E 1 1 A T H	1989																		
E 1 2 4 M H	1988																		
E 1 2 A M H	1989																		
E 1 3 2 L H	1987															+			+
E 1 3 2 L D																			
E 1 3 2 R g																			+
e																			+
s																			+

NEW CODE	1988 J	F	M	A	M	J	J	A	S	O	N	D
E 0 4 2 L H							+					
E 0 5 3 H H											+	
E 0 7 2 S H												
E 0 8 8 H H											+	
E 0 9 4 T H									*			
E 1 0 2 L H												
E 1 0 7 L H						+					+	
E 1 1 4 P H								+			+	
E 1 1 4 T H								+			+	
E 1 1 A T H												
E 1 2 4 M H								+			+	
E 1 2 A M H												
E 1 3 2 L H					+							
E 1 3 2 L D												
E 1 3 2 R g											+	
e											+	
s											+	

NEW CODE	1989 J	F	M	A	M	J	J	A	S	O	N	D
E 0 4 2 L H							*					
E 0 5 3 H H							+					
E 0 7 2 S H												
E 0 8 8 H H							+					
E 0 9 4 T H											*	
E 1 0 2 L H												
E 1 0 7 L H				+								
E 1 1 4 P H					+							
E 1 1 4 T H					+							
E 1 1 A T H								+				+
E 1 2 4 M H					+							
E 1 2 A M H								+				+
E 1 3 2 L H					+							+
E 1 3 2 L D												+
E 1 3 2 R g										+		
e										+		
s										+		

NEW CODE	1990 J	F	M	A	M	J	J	A	S	O	N	D
E 0 4 2 L H												
E 0 5 3 H H												
E 0 7 2 S H												
E 0 8 8 H H												
E 0 9 4 T H												
E 1 0 2 L H	+											
E 1 0 7 L H		+										
E 1 1 4 P H	+											
E 1 1 4 T H												
E 1 1 A T H												
E 1 2 4 M H	+											
E 1 2 A M H												
E 1 3 2 L H												
E 1 3 2 L D												
E 1 3 2 R g												
e												
s												

KEY TO CODING OF EXPERIMENTS

PLANS:		LOCATIONS:	
01	Tree and annual crop interaction	1	Hoskote
02	Tree with tree mixture	2	Devabal
03	Clinal spacing	3	Siddapura
04	Thinning E.camaldulensis	4	Varkodu
05	Thinning hybrid	5	Nanjapura
06	Foliar nutrient study	6	Purdhal
07	Field laboratory	7	Kalankatte
08	Selective thinning of hybrid euc.	8	Thammadihalli
09	Pine spacing	9	Umblayle
10	Eucalyptus fertilizer trial	A	Halwani
11	Pine fertilizer trial	B	Basavani
12	Acacia fertilzer trial	C	
13	Factorial spacing (was 3A)	D	
.		E	
.		.	
.		.	
.		.	
.		.	

SPECIES CODES:	
A	Acacia auriculiformis
C	Casuarina equisetifolia
H	Eucalyptus tereticornis x
L	Eucalyptus camaldulensis
M	Acacia mangium
P	Pinus caribaea var. hondurensis
T	Pinus patula ssp. tecunumanii
.	
.	

Experiment identifiers have the prefix 'E'.
Further localities are to be entered and coded when required.

E011 refers to the tree and annual crop experiment at Hoskote. Four further digits are available to identify blocks, treatments, species etc. as required.

P1 plot summaries for <u>Casuarina equisetifolia</u>; four assessments

Summary of measurements of permanent sample plots. File: C:mpm89ce.SUM

			AFTER THINNING									THINNINGS					
Age(yr)	N/ha	SI	Hdom	Ddom	H(L)	D	SumCS	MNCS	MDcop	G	SumV	N rem	D rem	G rem	V rem	V mean	Plot No.
			INCREMENT														
D.of P	CumG	CumV	CAI(G)	CAI(V)	MAI(G)	MAI(V)					Vol.model						
4.92	1600	22	12.0	7.6	8.5	5.3	0	0	0.0	3.6	18.6	0	0.0	0.00	0.0	0.0	M1040205
	4	18.6	0.00	0.0	0.73	3.8					4						
5.42	1600	24	11.1	8.7	9.5	6.0	0	0	0.0	4.5	27.6	0	0.0	0.00	0.0	0.0	M1040205
	5	27.6	1.89	18.0	0.84	5.1					4						
5.92	1600	20	13.5	9.6	10.5	6.4	0	0	0.0	5.2	34.8	0	0.0	0.00	0.0	0.0	M1040205
	5	34.8	1.39	14.5	0.86	5.9					4						
6.50	1600	17	15.8	9.7	11.2	6.9	0	0	0.0	5.9	51.7	0	0.0	0.00	0.0	0.0	M1040205
	6	51.7	1.24	28.9	0.92	8.0					4						
5.92	1250	20	15.0	10.5	12.5	7.0	50	2	0.0	4.9	40.0	0	0.0	0.00	0.0	0.0	M1040403
	5	40.0	0.00	0.0	0.82	6.8					4						
6.42	1250	19	16.0	10.9	13.7	7.4	50	2	0.0	5.3	48.8	0	0.0	0.00	0.0	0.0	M1040403
	5	48.8	0.92	17.7	0.83	7.6					4						
7.00	1250	18	17.1	11.3	14.7	7.7	50	2	0.0	5.8	60.2	0	0.0	0.00	0.0	0.0	M1040403
	6	60.2	0.80	19.4	0.83	8.6					4						
7.50	1250	18	16.9	12.0	15.3	8.1	50	2	0.0	6.4	68.4	0	0.0	0.00	0.0	0.0	M1040403
	6	68.4	1.21	16.5	0.85	9.1					4						
3.92	2600	19	10.9	8.6	10.0	5.6	200	2	0.0	6.5	37.7	0	0.0	0.00	0.0	0.0	M1070307
	6	37.7	0.00	0.0	1.65	9.6					4						
4.42	2600	17	12.2	9.3	11.6	6.2	200	2	0.0	7.9	55.7	0	0.0	0.00	0.0	0.0	M1070307
	8	55.7	2.95	36.1	1.80	12.6					4						
5.00	2600	15	14.1	9.7	12.3	6.5	200	2	0.0	8.6	65.6	0	0.0	0.00	0.0	0.0	M1070307
	9	65.6	1.12	17.0	1.72	13.1					4						
5.50	2400	16	13.5	10.5	13.8	7.1	200	2	0.0	9.4	89.1	200	2.4	0.09	0.4	0.0	M1070307
	10	89.5	1.84	47.8	1.73	16.3					4						
2.92	1450	35	8.2	8.2	8.4	6.3	0	0	0.0	4.5	19.8	0	0.0	0.00	0.0	0.0	M1070606
	5	19.8	0.00	0.0	1.56	6.8					4						
3.42	1450	29	9.9	9.3	10.0	7.2	0	0	0.0	5.9	32.3	0	0.0	0.00	0.0	0.0	M1070606
	6	32.3	2.70	24.9	1.72	9.4					4						
4.00	1450	24	11.6	10.2	11.5	7.9	0	0	0.0	7.1	44.7	0	0.0	0.00	0.0	0.0	M1070606
	7	44.7	1.99	21.3	1.76	11.2					4						
4.50	1450	21	13.4	11.0	13.3	8.5	0	0	0.0	8.2	61.1	0	0.0	0.00	0.0	0.0	M1070606
	8	61.1	2.31	32.9	1.82	13.6					4						

P1 plot summaries for Pinus caribaea; four assessments

Summary of measurements of permanent sample plots. File: C:mpm89pc.SUM

Age(yr) / D.of P	N/ha / CumG	S% / CumV	AFTER THINNING Hdom / INCREMENT CAI(G)	Ddom / CAI(V)	H(L) / MAI(G)	D / MAI(V)	SumCS	MNCS	MDcop	G	SumV / Vol.model	THINNINGS N rem	D rem	G rem	V rem	V mean	Plot No.
2.92	975	62	5.6	9.0	4.4	6.5	50	2	4.6	3.2	10.5	0	0.0	0.00	0.0	0.0	M301002 BE
	3	10.5	0.00	0.0	1.09	3.6					4						
3.42	1000	56	6.1	10.9	5.4	8.6	200	2	4.6	5.8	23.1	0	0.0	0.00	0.0	0.0	M301002 BE
	6	23.1	5.24	25.2	1.70	6.8					4						
3.92	1000	48	7.0	12.7	6.3	10.2	200	2	4.6	8.2	40.5	0	0.0	0.00	0.0	0.0	M301002 BE
	8	40.5	4.86	34.7	2.10	10.3					4						
4.50	975	46	7.5	15.0	7.4	11.9	200	2	4.6	10.9	59.7	25	10.2	0.20	0.5	0.0	M301002 BE
	11	60.1	4.89	33.7	2.46	13.4					4						
4.92	800	47	8.0	11.9	6.1	8.3	150	2	4.6	4.3	22.2	0	0.0	0.00	0.0	0.0	M1040304 N
	5	22.7	0.00	0.0	0.92	4.6					4						
5.42	800	41	9.2	14.1	7.2	10.1	150	2	4.6	6.5	40.1	0	0.0	0.00	0.0	0.0	M1040304 N
	7	40.6	4.26	35.7	1.23	7.5					4						
5.92	800	41	9.2	14.8	7.8	10.7	150	2	4.6	7.2	41.1	0	0.0	0.00	0.0	0.0	M1040304 N
	7	41.6	1.54	2.0	1.26	7.0					4						
6.50	800	40	9.4	16.4	8.5	12.6	150	2	4.6	10.0	48.6	0	0.0	0.00	0.0	0.0	M1040304 N
	10	49.1	4.70	12.9	1.57	7.6					4						
2.92	925	67	5.3	6.5	4.6	5.0	50	2	4.6	1.9	5.5	0	0.0	0.00	0.0	0.0	M1070203 G
	2	5.5	0.00	0.0	0.63	1.9					4						
3.42	925	56	6.3	9.2	5.9	7.6	50	2	4.6	4.2	16.0	0	0.0	0.00	0.0	0.0	M1070203 G
	4	16.0	4.63	21.1	1.22	4.7					4						
4.00	925	53	6.7	10.7	6.4	8.5	50	2	4.6	5.3	21.5	0	0.0	0.00	0.0	0.0	M1070203 G
	5	21.5	1.96	9.4	1.33	5.4					4						
4.50	925	46	7.7	12.2	7.8	10.3	50	2	4.6	7.7	45.5	0	0.0	0.00	0.0	0.0	M1070203 G
	8	45.5	4.85	48.0	1.72	10.1					4						
3.92	1025	62	5.4	9.3	4.6	6.4	200	2	4.6	3.3	10.2	0	0.0	0.00	0.0	0.0	M1070501 M
	3	10.2	0.00	0.0	0.84	2.6					4						
4.42	1025	52	6.4	11.8	5.6	8.8	200	2	4.6	6.3	26.1	0	0.0	0.00	0.0	0.0	M1070501 M
	6	26.1	6.01	31.8	1.43	5.9					4						
4.92	1025	42	8.1	14.4	6.6	10.2	200	2	4.6	8.3	45.8	0	0.0	0.00	0.0	0.0	M1070501 M
	8	45.8	4.10	39.4	1.70	9.3					4						
5.50	1025	38	8.8	15.5	7.9	11.3	200	2	4.6	10.2	64.8	0	0.0	0.00	0.0	0.0	M1070501 M
	10	64.8	3.20	32.5	1.86	11.8					4						

APPENDIX 6 - Format for recording D plot data (not inc. volumes)

PHYTOMASS MEASUREMENTS --- AND LEAF AREA JANUARY 1990

PLOT identifier: D1130202 HARMAGATTA 1984 PLANTATION PSP # 13

TREE: #	DBH HEIGHT cm/m	CROWN ST.	HT. BASE	LEAVES: TOTAL GW g	SAMPLE GW g	SAMPLE DW g	TOTAL DW g	LAI: SAMPLE LEAF AREA sq.cm	SAMPLE # LVS. Number	SAMPLE GW g
6	7.7	T	7.2	370	100.0	43.0	159.1		18	
	---------	M	5.8	527.6	100.0	48.9	258.0		10	
	8.3	B	4.32	1155.2	100.0	49.0	566.0		12	
	---------	Below B								
10	3.3	T	4.8	4.5	4.5	2.3	2.3		73	
	---------	M	4.56	7.2	7.2	3.4	3.4		91	
	5.2	B	3.9	186.3	100.0	46.5	86.6		97	
	---------	Below B								
15	4.5	T	5.33	107.5	100.0	41.5	44.6		83	
	---------	M	4.38	495.7	100.0	46.4	230.0		81	
	6.38	B	3.3	88.8	88.8	41.1	41.1		60	
	---------	Below B								

FLOWERS & FRUITS: TOTAL GW g	SAMPLE GW g	SAMPLE DW g	BRANCHES: TOTAL GW g	SAMPLE GW g	SAMPLE DW g	TOTAL DW g	STEMS:	TOTAL GW g	TOTAL DW g
			120.8	120.8	40.7	40.7	DBH	66.7	29.4
			98.2	98.2	42.9	42.9	BM	59.6	26.1
			233.3	200	102.5	119.6	CB	100.6	44.2
							CM	74.6	32.8
			163.1	163.1	63.4	63.4	DBH	148.7	67.4
			476.7	200	96.6	230.2	BM	40.7	18.3
			582.2	200	97.5	283.8	CB	132.2	59.6
							CM	78.6	35.5
			367.4	200	93.3	171.4	DBH	444.9	201.4
			807.1	200	100.7	406.4	BM	272.1	126.9
			886	200	113.3	501.9	CB	123.2	55.6
							CM	16.1	7.2

FAST-GROWING TREE PROJECT - KARNATAKA, INDIA.

Report No 45 following field visit May, 1990

A F Harrison, Institute of Terrestrial Ecology, Merlewood Research Station, Grange-over-sands, Cumbria LA11 6JU.

1 SUMMARY

The objective of A.F. Harrison's visit to India during May 1990 was to i) meet the Indian staff involved in the Project ii) become familiar with the aims, environmental conditions and field experiments of the project iii) assess the feasibility of applying bioassay techniques to determine tree nutrient status in the Eucalyptus, Acacia and Pine fertilizer experiments and Eucalyptus plantations iv) work out a practical scheme, including development of laboratory facilities, for implementing the research v) advise on the setting up of laboratory facilities for chemical analysis of plant, soil and water samples and vi) contribute any additional information of value to the project. It was clear from the discussions and the assessment of available expertise that good working relationships can be developed with the Indian staff. The application of the bioassay techniques to determine tree nutrient status is feasible and a scheme, including development of laboratory facilities, has been worked out. The field sampling programme will have to involve both MPM and possibly KFD staff and the laboratory facilities will be developed partly at MPM Paper Mills Bhadravati and partly at the Crop Physiology Department, University of Agricultural Sciences (UAS), Bangalore. Reasons for the use of laboratories at two locations are given in the text. The Crop Physiology and Soil Science laboratories UAS are recommended as the location for development of chemical analysis facilities.

During the field visits, a number of observations were made on the fertilizer experiments. Variation of planting stock and observed differences in heights of seedlings at planting were considered to be problems which may complicate the interpretation of the tree responses to fertilizer application. It has been suggested that covariance analysis may have to be applied, during the statistical analysis of the tree response data. The fate and positioning of fertilizer applied to improve tree growth has also been questioned. Nitrogen fertilizer applied as urea in the early monsoon period could be lost in significant amounts due to processes of soil leaching and/or volatilisation to the atmosphere. Also the NPK fertilizer is probably being placed too close to the stems of trees to be effectively utilised by trees. The fate of fertilizer and the best position with respect to tree stems should be investigated, to provide information for optimising the effectiveness of the applied fertilizers.

Suggestions for further research on the effects of eucalyptus and timber removal on soil fertility have been also made.

2 RECOMMENDATIONS

a) Root bioassays are applied to fertilizer experiments of *Eucalyptus camaldulensis* (Devabal) and *Pinus caribaea* and *Acacia mangium* (Varkodu) to assess the nutrient (P, K & N) status of trees and link this assessment with the observed tree responses to fertilizer application.

b) The same techniques are applied to eucalyptus in permanent plots in different sites around Shimoga to derive an expert system rule for predicting fertilizer requirement for optimum tree growth from site characteristics.

c) Covariance analysis is used during statistical analysis of tree growth data to overcome some observed problems likely to complicate interpretation of tree responses to fertilizer application.

d) The fate of applied fertilizer and the optimum zone and timing for its routine application around trees should be studied, as current application procedures may result in the effectiveness of the fertilizer being poor.

e) The potential of eucalyptus for causing the degradation of soils should be investigated, initially by examining effects on organic matter decomposition.

f) Laboratory facilities to carry out the nutrient (P,K & N) bioassay measurements are set up in the Crop Physiology Dept., University of Agricultural Sciences, Bangalore (P & K) and the MPM laboratories in Bhadravati (N). Reasons for the requirement of the two laboratories are given.

g) Laboratory facilities to carry out chemical analysis of plant, soil and water samples are established in the University of Agricultural Sciences.

3. Introduction.

Following the invitation to become involved in the project to provide tree nutrition and nutrient cycling expertise, it was necessary to visit the Indian organisations (Karnataka Forest Department and Mysore Paper Mills) and the field experiments in the areas of Bangalore and Shimoga. The visit occurred 1st May to 15th May 1990, when approximately one week was spent in each place.

3.1 The objectives of the visit for Dr Harrison were:

a. To become familiar with the overall objectives of the project.

b. To visit the main tree growth experiments which have been set up, to appreciate the environmental conditions, soil types, local forestry practices, and specifically the nature of the fertilizer trials at Devabal and Varkodu which he is to study.

c. To assess the situation regarding field and laboratory conditions, the logistics and practical aspects of applying the nutrient deficiency bioassays and any other research techniques considered necessary, to the fertilizer trials (*Eucalyptus camaldulensis, Pinus caribaea* and *Acacia mangium*) and permanent plots of eucalyptus.

d. To meet the staff of the Mysore Paper Mills, Karnataka Forest Department and University of Agricultural Sciences and assess their capabilities with respect to assisting with the application of bioassays and carrying out chemical analysis of plant and soil samples required in the project.

e. To make any appropriate recommendations to aid the success of the project.

4. Establishments and Field Sites Visited

4.1 Establishments

Purpose of the visits to the Indian forestry establishments was to meet staff with whom the research project is being conducted and be introduced to the respective Directors.

The establishments visited were:

i) Mysore Paper Mills Offices, Ali-Askar Rd, Bangalore

ii) Karnataka Forest Department (Aranya Bhavan), Malleswaram, Bangalore

iii) Karnataka Forest Dept Offices, Hosakote, Bangalore

iv) Crop Physiology and Soil Science (briefly) Departments, University of Agricultural Sciences, Hebbal, GKVK Campus, Bangalore

v) Karnataka Forest Dept Offices, Shimoga

vi) Mysore Paper Mills, Bhadravati, near Shimoga.

It was clear, from the discussions and the assessment of the expertise that good working relationships can be developed with all the Indian staff and the objectives of the project, in relation to the tree nutrition and nutrient cycling aspects, can be achieved. The necessary support facilities and expertise can be developed. Details of the practical aspects of the specific research programme and the possible scheduling of the activities are given below.

4.2 Field Sites and Experimental Conditions.

A good feel for the Experimental Forestry Research being carried out under the Project, the environmental conditions and an appreciation of the logistical aspects of carrying out the proposed research was obtained. Field Sites visited were

i) Hydrology studies in eucalyptus stands at Hosakote, near Bangalore

ii) Some of the Permanent plots of eucalyptus in the area around Hosakote

iii) Hydrology studies in eucalyptus and degraded forest at Puradal, Shimoga

iv) fertilizer trials on *Eucalyptus camaldulensis, Acacia mangium* and *Pinus caribaea* at Devabal, Varkodu, Halwani, Basvani and Kalanakatte.

v) Clinal spacing and thinning trials in eucalyptus at Devabal, Shimoga

vi) Species growth comparison trials at Devabal, Shimoga

vii) Site for potential hydrological study in moist-zone forest in the eastern edge of the Western Ghats mountains.

5. fertilizer Trials

5.1 Specific Objectives

The specific research objectives of the involvement of Dr Harrison in the project are:

a) To assess the growth responses of *Eucalyptus camaldulensis, Acacia mangium* and *Pinus caribaea* to applied fertilizer.

b) To provide a simple set of rules for determining the differences in fertilizer requirement of these species, in relation to site characteristics

c) To provide supporting information to account for fertilizer response patterns found.

These objectives will be carried out using a suite of nutrient deficiency bioassays, soil lysimetry or placement studies, as described below (section 6 and 7).

5.2 Experimental design

The fertilizer trials (see Experiment Plans 10 and 11, Karnataka Supplement P42) have been designed to assess the possible effects of nutrient limitations on plantation productivity and potential for growth improvement. The design, common to all experiments, is a factorial 3 x 3 x 2 NPK interaction with 2 replicate blocks giving a total of 36 plots (30m x 10m in size). Each plot is divided into three subplots, each containing 5 x 5 trees of which the centre 9 trees are measured. The three subplots will receive fertilizer in years 1, 1 & 2 and 1,2 & 3 respectively. Further details are contained in the supplement referred to above.

5.3 Observations by A F Harrison

Most of the experiments had been established for 2 years. From general observations, there did not appear to be clear cut fertilizer responses developing. This conclusion is borne out from a preliminary examination of the data. There seem to be a number of questions arising from this observation that need to be answered if the correct interpretations of the results of the experiments are to be obtained. If only small responses of the trees to fertilizer are found in these experiments, a modified research strategy will have to be adopted, to determine the main reasons for the poor tree response (see below).

i) A consequence of the initial variation at time of planting is that the method of analysis of the data used to assess the effects of the fertilizer application must involve techniques to remove the effects of significant differences in the initial sizes of the trees between blocks and treatments. A good example of the consequence of not taking this problem into account is given by the preliminary results of the fertilizer trial on Eucalyptus at Kalanakatte. The 'at planting height' values show that there were significantly bigger plants planted in block 2 (70.2 cm) compared to block 1 (54 cm). There was also significant bias in the P and PK treatments relative to those given N, in that the P2 treatments were shorter than the others. These initial effects of the P and PK biases had 'disappeared' in the height data after 2 years growth as there were then no significant differences revealed by ANOVA. This must mean that the P2 treatments had caught up during the 2 year growth period. Thus the provisional ANOVA on the 2 year height data, showing no differences between treatments, concealed this possible effect of the P2 and PK treatments, on the tree growth. Question 1 therefore is 'Can covariance analysis be used to peel off the effects of the initial sources of variation in the plant size, to reveal the real responses of the trees to the fertilizer applications ?'.

ii) Other explanations for the lack of clearly observable fertilizer effects on tree growth:

a) The fertilizer was applied in a suboptimal soil zone with respect to rooting activity. According to Mr Satishchandra (MPM, Shimoga), fertilizer is applied at 3 points 15 cms from the stem in the first year and 3 point sources 30 cms from the stem in subsequent years. In view of the rapid tree growth and the likely rapid root extension from the base of the tree, it may well be that the application is too close to the plant stem to be effective. Evidence to support this conclusion is that various tropical crops such as coconut, coffee, citrus and oil palm show optimal uptake in zones from 30 to 100cm from the stem and often at 15 to 30 cm depth in the soil. The zone of optimal uptake has been assessed in these studies by radioactive tracer techniques (IAEA, 1975). There are however interactions with the wet - dry season, age of the tree and soil type. No studies seem to have been carried out in these Indian plantations on the optimal zone or time of the year for fertilizer effects on tree growth. Question 2 is 'What is the optimal soil zonend application time ? and question 3 'How do these differ from the current practices ?'.

b) It is possible that the fertilizer particularly N fertilizer applied as urea, is leached (Ballard, 1981) or volatilised (Heilman et al, 1981) rapidly from the rooting zone after application; fertilizer is traditionally applied soon after the monsoons start. Also many iron-rich soils have a strong capacity to fix phosphate from fertilizer making it less available for plant uptake. Question 4 is 'Are fertilizers rapidly lost from or fixed in the root zone ?'.

c) The ratio of N:P:K applied is 1:1:1 and this is probably not the optimum ratio. The N content is probably too low (see Cromer *et al*, 1981), particularly in view of comments under b) above. Question 5 is "What is the optimum balance for N,P & K in the fertilizer and does it vary with site ?".

6. Application of the Nutrient Deficiency Bioassays to the fertilizer Trials

6.1 The root bioassays: aims

i) To determine whether there are nutrient deficiencies restricting the productivity of the *Eucalyptus camdulensis, Acacia mangium* and *Pinus caribaea* in the region of Shimoga,

ii) To assess whether the optimum amounts and balances of the nutrients in applied fertilizers have been covered by the treatments set up in the trials.

iii) To assess the relationships between the type of nutrient deficiency and site factors, such as rainfall, soil type, altitude etc from data for permanent plots of eucalyptus, and develop an expert system rule for routine application of fertilizer.

The nutrient deficiency bioassays are based on physiological responses of live feeder roots to the nutrient demand/soil supply balance in the forest or plantation. The bioassay determines the rate at which isotopically-labelled ions (32P, 86Rb and 15N) are taken up from a very dilute solution in the laboratory. The amounts measured are determined in terms of picograms (pg) to nanograms (ng) per milligram root and are from 1000 to 10,000 times smaller than can be measured by chemical analysis. Roots from deficient trees show a marked 'hunger response' in that their rates of uptake are much higher than those from trees with optimal nutrient supply (Harrison & Helliwell, 1979; Dighton & Harrison, 1983; Jones et al, 1987; Jones et al, in press). The bioassays are carried out in such a way that considerable numbers of root samples can be processed easily and simultaneously.

The major benefits of these techniques are:

i) The bioassays are more sensitive than conventional foliar analysis; indeed they frequently show the occurrence of deficiencies in trees that are not detected by measurement of foliar element concentrations. An example of this is given in Dighton & Harrison, (1990), where P deficiency was detected and confirmed by subsequent stem growth responses to fertilizer, in mid-rotation Sitka spruce stands in the UK. Foliar concentrations of P showed no differences across a range of stands covering the development sequence from planting to harvesting.

ii) The bioassays are rapidly carried out on large numbers (upto 300 per man day) of samples and are cost effective compared to foliar analyses, despite being more high-tech in nature.

iii) The bioassays can clearly demonstrate interactions in nutrient demands, such as effects of unbalanced supply of nutrients on growth e.g. effects of added P on the demand for N and K and vice versa again not readily detected by foliar analysis (see 5 ii c above).

These virtues of the bioassays have all recently been shown in their application to *Eucalyptus grandis*, in particular that the bioassays were able to demonstrate N, P and K deficiencies and fertilizer responses in trees, where foliar analysis did not (Dighton & Jones, in prep).

6.2 Practicality of Applying Root Bioassays

6.2.1 Specialist facilities

Despite requiring the use of isotopes, two of which (32P and 86Rb) are radioactive, the bioassays are very easy to carry out in a routine manner, are cost effective and present no safety problems provided adequate training is given. Their application to eucalyptus, acacia and pinus in the Fast-Growing Tree Project in India presents few problems, provided the appropriate isotope counting istrumentation is made available. The bioassays would initially be applied only by the ITE staff, with help from KFD and MPM staff in the root sampling programme. The required radioisotopes are available from the Indian Atomic Energy Authorities and the procedures for transport to Bangalore are already organised. Computing soft-ware for calculation of the complex results presents no problem as a micro-computer attached to the isotope equipment can be utilised off-line for the initial calculations. Final analysis of the data will be carried out at ITE Merlewood.

6.2.2 Laboratories

6.2.2.1 Radioisotope procedures

To carry out the bioassays for phosphorus and potassium nutrition assessments, which use the radioisotopes 32P and 86Rb, it is proposed to set up facilities in the Department of Crop Physiology at University of Agricultural Sciences, Hebbal, Bangalore. This department already has i) adequate experience with radioisotope techniques, ii) a permit to store, use and dispose of radioisotopes and iii) expertise in root physiological studies. It has in hand plans to upgrade its radioisotope laboratory with improved handling, storage and disposal facilities. Prof. M. Udaya Kumar Head of the Department is very willing to cooperate in the project and from discussions with him, it is clear he will be an excellent experienced collaborator. He is one of only two persons within the University campus with a permit to purchase radioisotopes from the Indian Atomic Energy Agency. His department already has a temperature-controlled room in which to house the computer-operated isotope counting equipment. The laboratory is situated about 300 km away from the field sites and despite this distance, it is possible to transport root samples under appropriate conditions to process there.

6.2.2.2 Stable isotope procedure

To carry out the bioassay for nitrogen nutrition assessment using the stable (non-radioactive) isotope 15N, it is proposed to set up the much simpler facilities required at the MPM laboratories in Bhadravati, near Shimoga. As no special permission or precautions are necessary for handling 15N, it is possible to carry out this bioassay procedure without any additions to or modifications of the laboratory. All that is necessary is about 3 m x 2m bench space and a sink with clean running water. After processing, the root samples will be dried and transported back to the UK where their 15N content will be determined by use of the NERC oxidiser mass spectrometer at ITE Merlewood. Transporting stable isotope-labelled materials by aircraft presents no saftey problems and infringes no legislation.

6.2.3 Logistics

The first fertilizer experiment to be investigated is the *Eucalyptus camaldulensis* trial at Devabal. This consists of two replicate blocks with 18 plots each with 3 subplots. Bearing in mind the statistical problems mentioned earlier in the report, and assuming these can be resolved by statistical manipulation, it is considered that taking 3 random replicate root samples per subplot will be an adequate sampling intensity for the application of the bioassays. With the factorial structure of the trials, there is considerable 'hidden replication' within the design, so that the effects of the treatments on tree nutrition should be easily revealed. Our experience with the application of all three bioassays in a eucalyptus fertilizer trial has provided us with a firm basis for this sampling intensity. The root bioassays will be applied in late September- October after the main summer monsoons. At this time the main tree growth period will have occurred and the trees will then be under the greatest nutrient deficiency stress and after the rains, soils will still be moist and the root activity of the trees will be greatest.

For the nitrogen bioassay, a period of one week is required to carry out the procedure. All preparations, coding of sample tags and setting up of laboratory equipment will be carried out the prior to the sampling programme being started. The strategy is to sample (total of 162 root samples) from each subplot of one block on one day (Monday) followed by sampling the other block on the following day (Tuesday). The next day roots and personel will be transported to the MPM laboratories in Bhadravati and roots from the first block processed that day (Wednesday) followed by those of the second block the following day (Thursday). On the Friday, root samples will be dried, bagged and labelled for transport back to the UK. For the field sampling and some parts of the root processing procedures, there will be a need for the assistance of 2 Indian staff (Graduate Junior Research Fellows). There is a standard delay between sampling and processing of the root samples; the technique is routinely used with this time delay. This delay is introduced to make handling of roots in the N bioassay consistent with those of the P and K bioassays.

For each of the P and K bioassays, a period of a week will be required. As with the N bioassay, the preparation of all equipment at the Crop Physiology Department, UAS will have been completed prior to the field sampling programme. With each of the bioassays, sampling of both blocks (total 324 root samples) will have to be carried out on the same day (Monday). For this to be possible, there will be a need for upto four Indian staff to assist. The following day (Tuesday) the roots and the ITE personel will be transported by car to Bangalore. The roots will be processed through the bioassay (with concomitant isotopic measurements) during the Wednesday, Thursday and Friday of the same week. Two Indian researchers from UAS will be required to assist in the procedure. All data capture for these two bioassays will be completed in India, thus no radioactive samples need to be transported outside of the UAS laboratories.

The same strategies will be adopted for assessment of acacia and pine fertilizer trials and the examination of the nutrient status of the permanent plots of eucalyptus, when these are assessed later in the project.

6.2.4 Statistical Analysis

All the data will be taken back to the UK for analysis. Analysis will be carried out at ITE Merlewood with advice from our statisticians as necessary. Relationships between the results of the bioassays and the tree responses to fertilizer application will also be assessed and interpreted.

6.2.5 Training of Indian staff

As the project proceeds, and the Indian staff of KFD and UAS become familiar with the bioassay techniques and isotope handling procedures, they will be encouraged to become increasingly involved in and take over the responsibility of the bioassay applications. They will also be taught how to operate the software programs for the preliminary calculation of the results.

6.2.6 Development of Radioisotope Facilities at Bhadravati

At present, there is no licence to use or experience in the use of radioisotopes at the Paper Mill laboratories in Bhadravati. Obtaining registration, permission to purchase, store and use radioisotopes, development of extra laboratory requirements such as acid disgestion and fume-hood extraction systems, and gaining of of research expertise in the bioassays would take too long and would hinder the progress of the project. Thus the travelling to Bangalore, at least in the early stages of the research, will have to be tolerated.

If as expected, these bioassay techniques prove effective in the diagnosis of nutrient deficiencies and it is considered appropriate, then the radioisotope facilities to MPM laboratories can be transferred later.

7. Modified Research Strategy

Significant responses by trees to applied fertilizer are expected, for the elemental contents (particularly nitrogen) of the soils are low. If however, the responses of trees to applied fertilizer are small and nutrient deficiencies are detected in the trees by the bioassay procedures, then the reasons for the poor responses will have to be understood. The research programme will be adjusted to provide the answers.

Under section 2, some possible reasons have been outlined. Two of the most likely explanations will be examined, namely the loss of nitrogen fertilizer by leaching or volatilisation and/or the wrong positioning of fertilizer with respect to root activity of the trees, resulting in poor fertilizer use by the trees.

7.1 Loss of N by leaching or volatilisation to the atmosphere

To study the degree of fertilizer N loss by soil leaching, a series of lysimeters will be set up in a range of locations under eucalyptus plantations. Soil water samples will be collected at intervals during a year following N fertilizer application and the amounts of nitrogen in the samples chemically analysed. The water samples will have to be analysed by a chemistry laboratory in Bangalore (see below). The proportion of the fertilizer N lost by leaching will be calculated and related to rainfall input and soil conditions. The timing of application of the N fertilizer with respect to leaching can be determined. ITE staff have obtained considerable experience over many years with lysimeter studies under forestry conditions.

To study the losses of urea N to the atmosphere as ammonium N, plastic tunnels about 30 cm high will be erected over areas to which urea has been applied and to control areas. At one end of each of the tunnels a small electric fan (run from a car battery) is used to blow air over a container of acid at the other end. Ammonium N in the atmosphere passing over the acid becomes trapped and the amounts of it can be determined by chemical analysis of the acid solution. Relative amounts from control and urea treated areas can be compared to indicate the importance of loss of urea N by this process. Chemical analysis of the acid for NH4 will be carried out in the chemistry laboratory in Bangalore.

7.2 Loss of phosphate by fixation

To assess the potential of the soils to chemically immobilise fertilizer phosphorus and reduce its availability to trees, samples of soils from rooting depth in the fertilizer experiments will be taken and their P fixing capacity will be determined, using the method of Bache & Williams (1971). Soils will be returned to the UK for these determinations. Harrison et al (1988) have had experience of determining P fixing capacity of a wide range of UK soil types.

7.3 Optimisation of fertilizer uptake

To study the location around a tree stem for optimum uptake of fertilizer, placement studies, using the radiosotope 32P according to the procedures outlined by IAEA (1975) will be set up in a suitable site under eucalyptus. Basically the procedures are to place small amounts of the isotope at specific distances and depths in the soil around trees and the amounts of the isotope reaching the tree foliage determined. The soil position resulting in the greatest uptake of the isotope will be the optimum for fertilizer uptake.

Similarly, the time of application with respect to optimum tree uptake can be determined using the same procedures. Harrison and Dighton have experience with these techniques (Harrison, Miles & Howard, 1988; Dighton et al, 1990).
The specialist analytical equipment and the laboratories required for this research will be exactly the same as that required for

carrying out the nutrient bioassays i.e. in the Crop Physiology Department UAS. Permission for field use of the radioisotope will have to be obtained from the appropriate Indian authorities before such experiments can be carried out.

7.4 Labour requirements

As with the application of the nutrient bioassays, Indian staff of either MPM or KFD will be required to assist in the fieldwork in the studies under items 7.1 and 7.3. Chemical analyses will require assistance of UAS staff. The amounts of manpower required will be greater than for the application of the bioassays but the exact amount is difficult to assess at this time because the level of involvement in the alternative studies will only come clear as the project proceeds.

7.5 Alterations to forest fertilisation practice

The results from the two sets of experiments in 7.1 and 7.3 will be used to decide if changes to the current fertilizer application practice is necessary and what the changes should be, in order to maximise the fertilizer effect on tree growth.

8. Development of Chemical Analysis Facilities

Of the laboratories seen, those of the Crop Physiology and Soil Science Departments UAS have some experience with sample chemical analysis. The members of staff were responsive to new ideas and will be receptive to training. The laboratory were maintained in a good clean condition suitable for analytical work. These laboratories should be considered as the base for analyses required in the project. Investment in staff training and equipment for chemical analysis of project samples, with emphasis on modern methods and attention to quality control procedures, is however required. No discussion has yet taken place with the staff of these departments regarding this possible development.

To carry out soil, foliar and lysimeter water analyses for the project at an adequate standard of precision, the major facilities needed are:

a) A block disgestor for acid digestion (dissolution of materials for total element analysis),

b) Atomic absorption spectrometer equipment (for cation analysis)

c) Colorimetric auto-analyser-spectrometer equipment (for total N, NH4, NO3 and PO4 analyses) equipment.

Additional smaller items e.g. multi-dose micropipettes, glassware, are also required to complete the laboratory facilities. ITE Chemical Analysis staff at Merlewood have considerable experience in setting up and equipping laboratories of this kind in

China, the Sudan and Kenya and have trained many students and researchers from different countries of Asia and Africa.

9. Other recommendations

During the visit to India, there was the opportunity to visit other experiments of the project and some of the permanent plots of eucalyptus. There were some additional observations of research merit raised by discussion during these visits.

i) Concern is growing that *Eucalyptus* species cause a reduction in the microbiological and decomposer activity in soils and this will result in a deterioration in the soil fertility. Planting eucalyptus in admixture with other tree species may help to alleviate this problem. A simple method of assessing the potential effects of different trees on microbial/decomposer activity is the Cotton Strip Assay (Harrison, Latter and Walton, 1988). The method has been able to demonstrate differences in the effects of trees, tree admixtures and tree species x seasonal interactions on soil microbial activity (Brown, 1988; Brown and Howson, 1988). The method is based on the rate of breakdown of a standard cotton cloth, buried perpendicularly in the soil profile, as measured by loss in tensile strength of the cloth. Standard textile testing machinery is used for the testing. Measurement of these parameters should be possible in India, through a textile producing company. The tensile testing machinery used to assess paper strength at the MPM Bhadravati laboratories is not strong enough for the purpose and cannot be modified.

ii) In the hydrological studies, the use of deuterium as a tracer for water movement is both costly and time-consuming. Tritium could be used instead of deuterium. It has a half life of 12.6 years and is a very weak beta emitter, so it presents little health hazard if used in appropriate amounts following the ALARA (As Low As Reasonably Achievable) principle. The measurement of tritium in water samples could easily be carried out on the radioisotope counting equipment requested for the nutrient bioassay research. The samples can be measured at a rate of up to 300 per day at a fraction of the cost and the measurements can be carried out in India without the need for transporting samples to the UK.

References

Bache, B.W. & Williams, E.G. (1971). A phosphate sorption index for soils. Journal of Soil Science 22, 289 - 301.

Ballard, R. (1981). Urea and ammonium nitrate as nitrogen sources for southern pine plantations. South. J. Appl. For. 5, 105 - 108.

Brown, A.H.F. (1988) Discrimination between the effects on soils of 4 tree species in pure and mixed stands using cotton strip assay. In: Cotton Strip Assay: An Index of Decomposition in Soils. Edited by A.F. Harrison, P.M. Latter and D.W.H. Walton.pp 80 - 85. Institute of Terrestrial Ecology, Grange-over-sands, UK.

Brown, A.H.F. & Howson, G. (1988). Changes in tensile strength loss of cotton strips with season and soil depth under 4 tree species. In: Cotton Strip Assay: An Index of Decomposition in Soils. Edited by A.F. Harrison, P.M. Latter and D.W.H. Walton.pp 86 - 89. Institute of Terrestrial Ecology, Grange-over-sands, UK.

Cromer, R.N. et al (1981). Response of Eucalypt species to fertilizer soon after planting at different sites. Aust. For. 44, 3 - 13. Dighton, J. & Harrison, (1983). Phosphorus nutrition of Lodgepole pine and Sitka spruce stands as indicated by a root bioassay. Forestry 56, 33-43.

Dighton, J. & Harrison, A.F. (1990). Changes in Phosphate Status of Sitka spruce plantations of increasing age, as determined by root bioassay. Forest Ecology & Management 31, 35-44.

Dighton J. & Jones, H.E. (in prep). The use of nutrient bioassays to assess the response of Eucalyptus grandis to fertilisation.

Dighton, J, Mason, P.A. & Harrison, A.F. (1990). The use of 32P tracer to measure phosphate uptake by mycorrhizas of Birch in the field: a preliminary study. In: Nutrient Cycling in Terrestrial Ecosystems, Field Methods, Application and Interpretation. Edited by A.F. Harrison, P. Ineson & O. W. Heal. pp389-399, Elsevier Applied Science Publishers, London.

Harrison, A. F. & Helliwell, D.R. (1979). A bioassay for comparing the phosphorus availability in soils. Journal of Applied Ecology 16, 497-505.

Harrison, A. F., Howard, D.M. & Lawson, G.J. (1988). UK Soils: Their phosphorus sorption capacity and potential for P removal from sewage effluents in emergent hydrophyte treatment systems. Report to the Water Research Centre, Stevenage, Herts, UK.

Harrison, A.F., Latter, P.M. & Walton, D.W.H. eds (1988) Cotton Strip Assay: An Index of Decomposition in Soils. pp 176 Institute of Terrestrial Ecology, Grange-over-sands, UK.

Harrison, A.F., Miles, J. and Howard, D.M. (1988). Phosphorus uptake by Birch from various depths in the soil. Forestry 61, 349-358.

Heilman, P.E. et al (1981). Season for application of urea fertilizer to Pacific Northwest forests. In: Proc. Forest Fertilization Conference. (Gessel, S.P., Kenady, R.M. & Atkinson, W.A. eds) pp 186-191. Univ. Washington.

I.A.E.A. (1975). Root Activity Patterns of Some Tree Crops. International Atomic Energy Agency, Vienna.

Jones, H. E., Harrison, A.F. & Dighton, J. (1987). A 86Rb bioassay to determine the potassium status of Trees. New Phytologist 107, 695-708.

Jones, H.E., Quarmby, C. & Harrison, A. F. (in press). A root bioassay test for nitrogen deficiency in forest trees. Forest Ecology & Management.

Appendix A

Cost Estimates of Various Activity Options
(Next 3 years only)

Regarding the studies on the nutritional status of Eucalyptus trees and their responses to fertilizer, three options have been costed. It should be noted that some margin of flexibility in the operations is however required, if the research is to adapt to the results of the experimentation as the project proceeds.

Option 1

Assessments of the nutritional P,K & N) status of Eucalyptus in both i) the fertilizer experiment and ii) plantation plots, each over three years, including setting up the isotope laboratory facilities and using the nutrient bioassay techniques.

Costs	1991	1992	1993	Total
Staff overheads)	42.5	41.8	46.3	130.6
Travel/Subsistence				
(UK)	0.4	0.4	0.4	1.2
(Overseas)	6.0	6.0	6.0	18.0
Scientific Equipment				
(scint count)	20.0	-	-	20.0
Customs duty	13.0	-	-	13.0
Consumables (incl isotopes)				
	2.0	2.0	2.0	6.0
Servicing Equipment				
	2.5	2.5	2.5	7.5
Computing	2.0	2.0	4.0	8.0
15N isotope analysis				
	13.5	18.5	18.0	49.0
Institute support	2.6	2.6	2.9	8.1
Totals	104.5	75.8	82.1	262.4

Option 2

The full activities of Option 1 plus i) examination of the losses of fertilizer nutrients by leaching (using lysimetry) and through N volatilisation (tunnel technique) and ii) isotope placement studies to determine soil zone for optimum fertilizer utilisation by trees.

Costs	1991	1992	1993	Total
Staff (incl. overheads)	42.5	94.1	84.2	220.8
Travel/Subsistence				
(UK)	0.4	0.4	0.4	1.2
(Overseas)	6.0	8.0	8.0	22.0
Scientific Equipment				
(scintillation counter)	20.0	-	-	20.0
Customs duty	13.0	-	-	13.0
Consumables (incl isotopes)	2.0	6.0	6.0	14.0
Servicing Equipment	2.5	2.5	2.5	7.5
Computing	2.0	2.0	4.0	8.0
15N isotope analysis	13.5	18.5	18.0	49.0
Institute support	2.6	6.1	5.2	13.9
Totals	104.5	137.6	128.3	370.4

Option 3

Assessments of the nutritional P,K & N) status of eucalyptus in both i) the fertilizer experiment (first year assessment) and ii) plantation plots over three years, including setting up the isotope laboratory facilities and using the nutrient bioassay techniques, plus i) examination of the losses of fertilizer nutrients by leaching (using lysimetry) and through N volatilisation (tunnel technique) and ii) isotope placement studies to determine soil zone for optimum fertilizer utilisation by trees.

Costs	1991	1992	1993	Total
Staff (incl. overheads)	42.5	73.5	65.3	181.3
Travel/Subsistence				
(UK)	0.4	0.4	0.4	1.2
(Overseas)	6.0	6.0	6.0	18.0
Scientific Equipment				
(scint count)	20.0	-	-	20.0
Customs duty	13.0	-	-	13.0
Consumables (incl isotopes)	2.0	6.0	6.0	14.0
Servicing Equipment	2.5	2.5	2.5	7.5
Computing	2.0	2.0	4.0	8.0
15N isotope analysis	3.5	9.0	9.0	31.5
Institute support	2.6	2.6	2.9	8.1
Totals	104.5	102.0	96.1	302.6

Setting Up Chemical Analysis Facilities

Setting up a chemical laboratory with Atomic absorption spectrometry and colorimetric auto-analysis spectrometry and associated sample preparation equipment, plus the necessary training of Indian staff both in India and in the UK.

Costs	1991	1992	Total
Staff (incl. overheads)	12.6	8.4	21.00
Travel/Subsistence			
(UK)	3.0	0.5	3.5
(Overseas)	6.0	3.5	9.5
Scientific Equipment			
(Analytical instruments)	38.0	-	38.0
Customs duty	??.?	-	??.?
Consumables (chemical etc)	3.0	?	3.0
Institute support	1.7	0.6	2.3
Totals	64.3	12.9	77.2

Effects of eucalyptus on soil microbial/decomposition properties.

Application of the Cotton Strip assay to the Species Growth and Nutrition Trial (Expt Plan No 7*) and the eucalyptus x acacia tree x tree species admixture trial (Expt Plan No 2*) to assess the impact of eucalyptus on soil microbial/decomposition properties.

Costs	1991	1992	Total
Staff (incl. overheads)	10.25	10.0	20.25
Travel/Subsistence			
(UK)	0.25	0.25	0.5
(Overseas)	5.7	5.7	11.4
Scientific Equipment			
(Hire/servicing)	1.0	1.0	2.0
Consumables	0.4	0.4	0.8
Computing	0.5	0.5	1.0
Institute support	0.55	0.55	1.1
Totals	18.65	18.4	37.05

* Supplement to the 'Guide to the establishment, measurement and analysis of permanent sample plots' 10th Dec. 1987 by P. Adlard).

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