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AN INVESTIGATION INTO THE EFFECT OF MONOCULTURAL PLANTATIONS OF *EUCALYPTUS CAMALDULENSIS* ON SOIL FERTILITY STATUS

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Abstract

The effect of Eucalyptus camaldulensis *monoculture on soil fertility status in the dry zone was studied comparatively with another monoculture of* Tectona grandis *and a natural forest located in the same area over a period of* 5 *months.*

Total litter production of Eucalyptus *was* 370.68 *kg/ha as compared with* 1349.07 *kg/ha in* Tectona grandis (*study period overlapped the leaf senescence*) *and* 217.75 *kg/ha in the natural forest. Litter decomposition was* 40.22% *in* Eucalyptus *while it was* 40.27% *and* 44.95% *in natural forest, and* Tectona *respectively. Nutrient release to litter at the time of fall did not differ between the vegetation types. However, it differed between the tree components and nutrients, the orders being leaves>twigs>bark and N>P>K>Ca.*

Significant differences ($p \geqslant 0.05$) *were seen in moisture content, pH, organic matter content, total nitrogen percentage, available potassium and calcium between the soils in the vegetation types.*

Key words: Monoculture plantations, *Eucalyptus*, Soil fertility.

1. Introduction

Eucalyptus, a native of Australia was introduced to Sri Lanka as early as the 18th century. Since then a large number of species have been tried in various parts of the country. *Eucalyptus* is an ideal species for plantation forestry due to its fast growth, adaptation to various climatic and edaphic conditions and the ability to coppice vigorously and repeatedly. *Eucalyptus camaldulensis* has become a popular species for dry zone reforestation. It meets the requirement of fuelwood, smallwood, pulpwood etc. The wood of *E. camaldulensis* is excellent for fuel and pulp and is also resistant to termites. It possesses a calorific value of 4752 kcal/kg (Steinback and Wijesinghe, 1982). Over 400 hectares of *E. camaldulensis* are planted every year in the dry zone. The total area planted in the dry zone upto the year 1988 is 22,448 hectares (Forest Department Plantation Record, 1988).

Despite their attraction as useful exotics, doubts had been raised as to whether eucalypts especially as monocultures have any adverse effect on soil fertility, soil structure and ground water table. However, there is a dearth of scientific data to rely upon regarding this in Sri Lanka. Therefore, the present study was undertaken to find out the effect of *Eucalyptus camaldulensis* on the fertility status of the soil in the dry zone.

2. Materials and Methods

2.1 Study site

This experiment was conducted in Wanniyagama Forest Reserve, situated about 27 miles east of Puttalam on the Puttalam–Anuradhapura road in the Puttalam Forest Division in the dry zone of Sri Lanka. It is 2m above msl and the mean annual rainfall is 1100mm with a drought period of about 5 months. The topography of the area is gently sloping and the main soil type a sandy loam with a good drainage.

2.2 Materials

A 14 years old *Eucalyptus camaldulensis* monoculture (2 x 2m spaced), a similar aged *Tectona grandis* monoculture (2 x 2m spaced), a natural forest and a bare land situated in the same locality were selected for the study.

2.3 Litter sampling

Five litter cages each (1 x 1m) were set up at random in *Eucalyptus*, *Tectona* plantations and in the natural forest on 16.12.89 with a view to compare the litterfall in these vegetation types. Furthermore, samples of fresh litter were- collected from the floor of the above vegetation types, divided into their res pective components (leaves, twigs and bark), weighed and were put into nylon mesh bags which were made of 3 compartments to fit in the litter. These bags were fixed onto the ground with the aid of pegs and left to decompose. Ten litter bags of this type were placed in each vegetation type. Afterwards samples of more freshly fallen litter were collected and taken to the laboratory in clean polythene bags for nutrient analysis.

Leaf, twig and bark samples (which ultimately form the litter) were also taken from standing trees of *Eucalyptus*, *Tectona* and the natural forest for the analysis of nutrients.

On 16.5.90, five months after the initiation of the experiment, litterbags were collected from the vegetation types, weighed (to measure the decomposition rate) and analysed for nutrients. Total nitrogen was analysed by mega kjeldahl digestion, available phosphorus by molybdenum blue method, available potassium, calcium by flame photometer (Allen, 1974).

2.4 Collection of soil samples

Five pits were dug depending on the terrain in each vegetation type. Each pit was 100cm deep and 3 soil samples collected separately from each depth; (0-15cm), (15-30cm), (30-45cm), (45-60cm), (60-80cm) and (80-100cm). In this way there was a total of 360 soil samples. Physical characteristics such as porosity and bulk density were determined for all soil samples. Then these samples were oven dried at 105°C to a constant weight and representative samples taken for the analysis of moisture content (oven dry basis), pH, organic matter percentage (Walkey Black method), cation exchange capacity (CEC), total nitrogen percentage (mega kjeldahl digestion,) available phosphorus (molybdenum blue method), available potassium and calcium (flame photometer).

2.5 Statistical analysis

Dry weight and nutrient data were analysed using analysis of variance. Tukey's multiple comparison tests were carried out where necessary to find pairwise differences for various tree and soil parameters measured in the study. Relationships between variables were examined by calculating Pearson Correlation Coefficients. All analysis were carried out using SPSSPC+ statistical package.

3. Results

3.1 Litter Production

Data on litter production from all vegetation types were collected over a period of 5 months and are given in Table 1.

Table 1. Litter production in *E. camaldulensis*, *Tectona grandis* and the natural forest over a period of 5 months

Vegetation type	Litterfall (kg/ha)
Natural Forest	217.75
E. camaldulensis	370.68
Tectona grandis	1349.07

3.2 Nutrient return through litterfall

Chemical analysis of litter samples for the estimation of various nutrient elements are shown in Table 11.

Table II. Nutrient contents of standing trees and fresh litter and the percentage returned at litterfall

Vegetation type	*nutrient*	*litter component*	*standing tree (%)*	*fresh litter (%)*	*% nutrient release to litter*
Natural Forest	nitrogen	leaves	1.90	1.75	92.10
		bark	1.85	1.25	67.56
		twigs	1.81	1.65	90.85
	pyosphorus	leaves	0.15	0.12	85.71
		bark	0.13	0.06	46.42
		twigs	0.14	0.07	48.00
	potassium	leaves	0.70	0.57	81.17
		bark	0.33	0.08	25.71
		twigs	0.43	0.14	33.33
	calcium	leaves	0.18	0.18	94.75
		bark	0.23	0.03	13.04
		twigs	0.19	0.18	94.73
Eucalyptus camaldulensis	nitrogen	leaves	1.44	1.25	87.04
		bark	1.85	0.81	22.95
		twigs	1.65	1.20	72.84
	phosphorus	leaves	0.17	0.16	94.73
		bark	0.10	0.03	35.71
		twigs	0.14	0.09	61.76
	potassium	leaves	0.60	0.40	65.91
		bark	0.44	0.14	31.66
		twigs	0.33	0.16	46.96
	calcium	leaves	0.27	0.07	26.92
		bark	0.60	0.27	44.44
		twigs	0.26	0.03	11.66
Tectona grandis	nitrogen	leaves	0.20	1.80	90.00
		bark	1.01	0.80	79.20
		twigs	1.67	1.50	90.36
	phosphorus	leaves	0.31	0.18	57.69
		bark	0.23	0.08	34.78
		twigs	0.13	0.06	45.16
	potassium	leaves	0.44	0.33	75.00
		bark	0.45	0.19	42.69
		twigs	0.33	0.22	65.15
	calcium	leaves	0.45	0.14	31.11
		bark	0.46	0.27	58.69
		twigs	0.23	0.04	15.21

3.3 Litter decomposition

The percentage decomposition of the litter components taken separately in all 3 vegetation types are shown in Table III.

Table III. Percentage decomposition of litter over a period of 5 months in the vegetation types.

Vegetation type	*litter component*	*% Decomposed*
Natural Forest	leaves	50.00
	bark	37.50
	twigs	33.33
E. camaldulensis	leaves	60.00
	bark	31.82
	twigs	28.85
Tectona grandis	leaves	61.54
	bark	43.33
	twigs	30.00

Significant differences ($p<0.05$) were not seen in percentage decomposition between the vegetation types. In general, leaves showed the highest rate of decomposition followed by bark and then the twigs.

3.4 Soil characteristics under the vegetation types

Physical and chemical characteristics of soil taken at different soil depths under these vegetation types and bare soil (control) are shown in Table IV.

***Table* IV.** **Physicial and chemical characteristics of soil under the vegetation types and the bare soil (control).**

Veg. Type	Depth	Porosity %	B. Density (g/scm)	Moisture content %	pH	Organic Matter %	Phosphorus (ppm)	Potassim (Meq)	C E C (Meq/100g)	Calcium (Meq)	Total nitrogen %
1	1	56.69	1.15	6.69	6.10	2.67	0.92	9.04	9.09	4.99	0.38
1	2	55 03	1.19	8.44	5.67	2.37	0.77	6.63	9.69	0.41	0.45
1	3	61.59	1.02	95.6	5.01	2.18	0.68	6.61	9.97	9.90	0.34
1	4	55.60	1.18	9.41	5.80	2.00	0.83	6.09	11.28	10.19	0.30
1	5	52.20	1.27	9.97	5.80	1.94	0.28	6.13	11.48	10.36	0.20
1	6	57.28	1.13	10.30	5.61	1.81	0.12	6.18	6.49	15.93	0.20
2	1	55.75	1.17	6.23	6.33	2.38	1.95	9.80	10.05	6.96	0.35
2	2	43.72	1.10	7.13	5.62	1.58	0.75	6.22	9.78	13.22	0.34
2	3	59.54	1.07	7.40	5.39	1.47	0.27	7.15	9.13	13.30	0.55
2	4	62.20	1.00	7.96	4.50	1.26	0.30	5.99	10.48	15.80	0.04
2	5	62.33	0.99	8.36	4.54	1.18	0.53	4.99	11.88	19.29	0.20
2	6	59.10	1.08	7.99	4.56	1.42	0.28	4.96	11.50	19.29	0.23
3	1	43.08	1.15	8.99	6.72	2.71	0.73	9.98	11.69	17.00	0.60
3	2	55.89	1.09	8.23	6.09	1.87	1.12	7.30	11.69	13.02	0.95
3	3	54.29	1.11	8.96	6.27	2.13	0.86	8.03	11.62	12.48	0.55
3	4	56.33	1.16	9.24	5.80	2.13	0.29	4.91	11.39	12.54	0.74
3	5	59.42	1.08	9.88	5.65	3.20	1.43	6.05	11.87	11.89	0.50
3	6	59.33	1.08	10.82	5.56	2.90	1.31	4.15	11.27	14.41	0.40
4	1	57.58	1.12	5.93	7.40	0.43	0.54	0.30	10.76	4.38	0.39
4	2	60.08	1.06	8.06	7.90	0.25	1.73	0.30	10.53	4.33	0.30
4	3	55.08	1.19	7,65	7.97	0.47	1.51	0.29	11.07	6.99	0.20
4	4	56.99	1.14	8.83	7.87	0.48	1.11	0.45	10.78	7.51	0.10
4	5	59.83	1.06	8.83	8.39	0.91	0.77	0.37	11.79	8.69	0.10
4	5	59.83	1.06	8.83	8.39	0.91	0.77	0.37	11.79	8.69	0.10
4	6	58.26	1.14	6.37	7.67	0.75	0.88	0.19	11.32	12.22	0.04

Veg. Type

1 — Natural Forest
2 — *Eucalyptus camaldulensis*
3 — *Tectona grandis*
4 — bare soil (control)

Depth

1 — 0-15cm
2 — 16-30cm
3 — 31-45cm
4 — 46-60cm
5 — 61-80cm
6 — 81-100cm

Significant differences ($p<0.05$) were observed in percentage moisture content, pH, cation exchange capacity (CEC), percentage organic matter, total nitrogen percentage, available potassium and calcium contents between the vegetation types and the bare soil.

Only percentage moisture content, total nitrogen percentage, available potassium and calcium varied significantly ($p<0.05$) with the depth of soil.

The results of Tukey's multiple comparison test for differences between vegetation types and bare soil in soil characteristics tested are shown in Table V (matrix of comparison) while the differences between soil depths are shown in Table VI.

Table V. Matrix of comparison for differences between pairs of treatments (vegetation types and control) in soil characteristics,

a) moisture content

		treatments			
mean	treatments	4	2	1	3
7.61	4				
7.51	2				
8.89	1	*			
9.35	3	*	*		

b) pH

		treatments			
mean	treatments	2	1	3	4
5.16	2				
5.67	1				
6.02	3	*			
7.87	4	*	*	*	

c) organic matter

		treatments			
		4	2	1	3
mean	treatments				
0.55	4				
1.55	2	*			
2.16	1	*			
2.49	3	*	*		

d) cation exchange capacity

		treatments			
		4	2	1	3
mean	treatments				
9.67	4				
10.47	2				
11.04	1				
11.59	3	*			

(Continued on next page)

e) available potassium

		treatments			
		4	2	3	1
mean	treatments				
0.32	4				
6.52	2	*			
6.74	3	*			
6.78	1	*			

f) total nitrogen percentage

		treatments			
		4	2	1	3
mean	treatments				
0.19	4				
0.29	2				
0.32	1				
0.63	3	*	*	*	

g) available calcium

		treatments			
		4	1	3	2
mean	treatments				
7.35	4				
8.63	1				
13.57	3	*			
14.64	2	*	*		

* significant at 0.05 level

treatments
1 — natural forest
2 — *Eucalyptus camaldulensis*
3 — *Tectona grandis*
4 — bare land

Table VI: Matrix of comparison for differences between pairs of treatments (soil depths) in soil characteristics

a) moisture content

mean	treatments	treatments 1	2	3	4	5	6
6.96	1						
7.97	2						
8.14	3						
8.86	4	*					
8.87	6	*					
9.26	5	*					

b) available potassium

mean	treatments	treatments 6	4	5	2	3	1
3.87	6						
4.36	4						
4.39	5						
5.11	2						
5.52	3						
7.28	1	*	*	*			

c) total nitrogen percentage

mean	treatments	treatments 6	5	4	3	1	2
0.22	6						
0.25	5						
0.30	4						
0.41	3						
0.43	1						
0.51	2	*					

d) available calcium

mean	treatments	treatments 2	1	3	4	5	6
7.74	2						
8.35	1						
10.67	3						
11.51	4						
12.56	5						
15.46	6	*					

* significant at 0.05 level

treatments

1 —	0-15cm	4 —	46- 60cm
2 —	16-30cm	5 —	61- 80cm
3 —	31-45cm	6 —	81-100cm

Correlation between the soil characteristics observed are shown in Table VII.

Table VII. Correlation matrix of the soil characteristics measured in the study

	PORO	BDEN	MC	pH	OM	P	K	CEC	CA	N
PORO		*								
BDEN	*									
MC										
PH					*	*	*		*	
OM				*			**			*
P				*						
K				**	**					*
CEC										
CA				*						
N					*		*			

* — Significance at 0.05 level
** — significance at 0.01 level

key

PORO	porosity
BDEN	bulk density
MC	moisture content
pH	
OM	organic matter
P	phosphorus
K	potassium
CEC	cation exchange capacity
CA	calcium
N	nitrogen

4. Discussion

An attempt has been made to compare the litterfall and nutrient status of *Eucalyptus camaldulensis* monoculture with another monocultural plantation of *Tectona grandis*, an accepted exotic in Sri Lanka which is devoid of any reported effects on the environment. A natural forest was included in the study to compare the degree of deviation these plantations show from a naturalized condition. The bare soil was used as a control. The existing controversy over the planting of eucalypts in the form of monoculture being harmful to soil nutrient status especially in the dry zone necessitated a study of this nature. Despite the doubts raised by Narain (1982) quoted by Shiva and Bandyopadhyay (1987) that the total mineral content of the litter of eucalypts are lower than that of indigenous tree species, a significant difference ($p<0.05$) was not observed in this regard between the vegetation types studied in the present study (Table II). However. the litterfall measured over a period of 5 months in *Eucalyptus camaldulensis* was inferior to that of *Tectona grandis* though superior to that of the natural forest. This observation is in agreement with that of Pradhan and Dayal (1981) quoted by Gupta (1986) who reported the annual litter production to be 4600 kg/ha in *Tectona grandis* while it was only 1800 kg/ha in *Eucalyptus*, in India. The high litterfall observed in *Tectona* in the present study was influenced by the fact that observations were carried out during its leaf senescence period. Unlike *Tectona*, *Eucalyptus* do not have a particular period for leaf shedding.

The observations of the present study regarding the rate of decomposition of *Eucalyptus* litter did not confer with the speculations put forward by doubtors who claimed that eucalyptus litter takes a longer time to get fully decomposed when compared with indigenous species. A significant difference, ($p\leq0.05$) was not observed between the vegetation types in the rate of decomposition which implied that when fallen on to the ground, *Eucalyptus* litter behaves very much the same way as that of *Tectona* and also the trees in the natural forest.

Of the litter components, leaves exhibited the highest amount of nutrient return followed by twigs and then the bark in all the vegetation types (Table II). Similar trends were reported by George (1986) on *Eucalyptus* hybrid in India. Of the nutrients in standing trees, maximum return to litter was seen in nitrogen followed by phosphorus, potassium and calcium (Table II). This, however, was at variance with the observations of George (1986) on *Eucalyptus* hybrid where the order was $Ca > N > K > P > Mg$. Significant differences ($p \leq 0.05$) were not observed in porosity and bulk desnsity in the soils under the vegetation types implying that *Eucalyptus* do not affect the soil structure adversely. However, although higher than in the bare soil, the moisture content was significantly ($p\leq0.05$) low in soils under *Eucalyptus camaldulensis*. This could be attributable to the fact that being a fast growing species its water requirement too is high, thus the reduction of moisture content especially in the lower soil layers. This phenomenon could be due to the fact that being a fast growing species with relatively low transpiration rate (Kumar, 1984) it absorbs moisture from deeper layers and increases the moisture content around the root zone. It is of interest to note that Jha and Pande (1984) reported a tendency to retain more water in soils under *Eucalyptus camaldulensis* when compared with those of *Shorea robusta* in Dehra Dun, India. The observations of Kushalappa (1986) too reported similar trends on *Eucalyptus* hybrid, also in India.

Although the pH was around 6 in the surface soil layers under all the vegetation types, this tended to become slightly acidic with the increase in depth (Table IV). This was more prominent in *Eucalyptus* in the following soil depths: 46-60cm, 61-80cm and 81-100cm. However, this effect was not statistically significant. The bare soil was alkaline in all depths. Poore and Fries (1985) quoted Jammet (1975) who reported similar findings where soils under *Eucalyptus* tended to be weakly acidic with the increase of depth. However, when taken overall, the pH under eucalyptus was higher than under pines in the above study. Evidence contradictory to these were reported by Jha and Pande (1984) on *Eucalyptus camaldulensis* and Kushalappa (1986) on *Eucalyptus* hybrid in India who observed a variation from acidic to neutral with the increase of depth in soils under eucalypts. The highest organic matter content in the present study was observed in *Tectona* followed by the natural forest and then *Eucalyptus*. The bare soil showed the least. The high organic matter content observed in *Tectona* may have been strongly influenced by the fact that observations were carried out during the time of its leaf senescence. Singhal (1984) in a comparative study on *Eucalyptus* hybrid and *Shorea robusta* in India, observed a higher organic matter content in the soils under *Shorea* when compared with those under *Eucalyptus*. However, the quantity of organic matter humified was more under *Eucalyptus*. Moreover, he reported that since the humification rate was faster in *Eucalyptus* the chances of loss of organic matter was also considerably reduced. This is further endorsed by the observations of Jha and Pande (1984). They compared monocultural plantations of *E. camaldulensis* (20 yrs.) and *Shorea robusta* (60 yrs.) with natural sal forests in Dehra Dun, India, and reported that none of the monocultures could surpass the natural sal in organic matter accumulation. Still, a 14 years old monoculture of eucalypts showed higher accumulation of organic matter than a monoculture of sal. The correlation of organic matter content and total nitrogen percentage in all the soils tested in the present study is interesting.

The relatively low total nitrogen content, available potassium observed in soils under *Eucalyptus* in the present study, is at variance with the observations of Jha and Pande (1984) who reported these parameters to be higher in soils under *Eucalyptus camaldulensis* (14 yrs.) when compared with those under *Shorea robusta* in Dehra Dun, India. Evidence to a similar effect could be obtained from the observations of Kushalappa (1986) on *Eucalyptus* hybrid, also in India. Therefore, in the presence of a relatively high decomposition rate ad higher amount of nutrients in the litter, it could be speculated that more nutrients could be lodged in the understorey of *Eucalyptus camaldulensis* as suggested by Gupta (1986) for eucalyptus in India.

5. Conclusion

During the preliminary observations over a short time span, the data obtained showed that although inferior to *Tectona grandis*, *Eucalyptus camaldulensis* produced considerable amount of litter having a comparable amount of mineral nutrients to *Tectona grandis* and the natural forest.

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