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Litter fall, nutrient return and leaf decomposition in an age series of eucalypt plantations in Central Himalaya

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Abstract. Pattern of litter fall, nutrient return and leaf litter decomposition in 1 to 8-yr-old *Eucalyptus tereticornis* Sm. plantations are described. The input of litter and nutrients increased with increasing plantation age. The total calculated tree litter input ranged from 0.4(1-yr-old) - 6.5. t ha^{-1} yr^{-1} (8-yr-old plantation). Total annual nutrient return in Kg ha^{-1} through litter fall amounted to 62.3-75.6 N, 4.1-4.3 P and 27.9-30.6 K. The rate of decomposition decreased from 1-yr-old plantation to 8-yr-old plantation. In 1 and 2-yr-old plantation, about 98% weight loss occurred in 14 months whereas, in rest of plantations 96-98.7% weight loss occurred at the end of 16 months.

Key words: Litter production, seasonal variation, nutrient content, litter decomposition

Introduction

The importance of litter production in the forest ecosystems has long been recognized because the majority of organic matter produced by plants through photosynthesis is returned to the soil as litter. Litter fall may be seasonal or continuous and represents one of most important pathway for the transfer of energy and material.

Proctor *et al.* (1983) pointed out that when leaf fall estimates are properly combined with other measurements of biomass standing crop and fluxes, much information on production, decomposition and nutrient cycling can be gained. A substantial amount of organic matter produced by plants through photosynthesis is returned to the soil as litter. While a big portion of nutrient from the soil remains locked up in more permanent parts of the tree, a significant fraction is brought back to the soil surface and is released for re-use through a higly efficient decomposer system.

The decomposition subsystem performs two major functions, the mineralization of essential elements and formation of soil organic matter. The ways in which these two processes are accomplished, determine to a large extent, the structural and functional features of ecosystems. The rate of movement of essential nutrients through decomposition is an important regulator of primary production.

In the tarai belt (an area of superabundant surface water) of Central Himalaya the monocultures of *Eucalyptus terenicornis* has been planted over a large area. The

Age of plantation (years)	Leaf	Wood	Bark	Reproductive parts	Total
1	0.38±0.048	0.02±0.003	-	-	0.40
2	0.58±0.036	0.10±0.020	0.03±0.002	-	0.81
3	1.16±0.091	0.46±0.048	0.05±0.003	-	1.67
4	2.02±0.121	0.67±0.037	0.10±0.003	-	2.79
5	2.43±0.460	1.08±0.049	0.15±0.012	0.004±0.001	3.66
6	2.94±0.521	1.77±0.084	0.19±0.026	0.01 ±0.004	4.91
7	3.23±0.722	2.20±0.321	0.31±0.021	0.01 ±0.002	5.75
8	3.59±0.496	2.53±0.426	0.36±0.074	0.02 ±0.002	6.50

Table 1. Annual litter fall (t ha^{-1}± SE) in 1 to 8-yr-old *Eucalyptus* plantations.

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Nutrients	Components		Plantation age (years) 1	2	3	4	5	6	7	8
NITROGEN										
	Tree	Leaf	0.900±0.064	0.897±0.060	0.898±0.058	0.905±0.069	0.909±0.067	0.900±0.067	0.901±0.063	0.906±0.065
		Wood	0.329±0.061	0.330±0.024	0.372±0.014	0.371±0.015	0.365±0.027	0.366±0.031	0.370±0.017	0.368±0.022
		Bark	-	0.290±0.009	0.321±0.023	0.316±0.031	0.309±0.007	0.324±0.005	0.330±0.032	0.232±0.050
		Reproductive parts	-	-	-	-	0.742±0.042	0.779±0.070	0.801±0.012	0.794±0.024
	Shrub	Leaf	-	-	-	-	1.291±0.025	1.313±0.029	1.314±0.014	1.315±0.041
	Herb	Leaf	2.030±0.187	2.022±0.085	1.970±0.173	1.982±0.087	1.980±0.087	1.840±0.112	1.870±0.147	1.840±0.160
PHOSPHORUS										
	Tree	Leaf	0.051±0.004	0.053±0.004	0.052±0.004	0.053±0.002	0.055±0.004	0.055±0.004	0.055±0.004	0.056±0.003
		Wood	0.004±0.001	0.005±0.001	0.006±0.001	0.005±0.001	0.006±0.001	0.006±0.001	0.007±0.001	0.007±0.001
		Bark	-	0.005±0.002	0.007±0.001	0.007±0.002	0.007±0.002	0.007±0.001	0.008±0.003	0.008±0.002
		Reproductive parts	-	-	-	-	0.021±0.006	0.024±0.008	0.025±0.004	0.025±0.004
	Shrub	Leaf	-	-	-	-	0.132±0.003	0.130±0.003	0.128±0.002	0.129±0.003
	Herb	Leaf	0.136±0.021	0.138±0.028	0.104±0.021	0.116±0.024	0.106±0.024	0.110±0.009	0.109±0.013	0.109±0.022
POTASSIUM										
	Tree	Leaf	0.310±0.021	0.312±0.023	0.315±0.023	0.316±0.023	0.319±0.022	0.319±0.023	0.320±0.023	0.320±0.023
		Wood	0.044±0.012	0.046±0.011	0.050±0.002	0.051±0.002	0.051±0.002	0.052±0.003	0.052±0.002	0.053±0.003
		Bark	-	0.039±0.012	0.042±0.014	0.045±0.012	0.044±0.016	0.046±0.009	0.048±0.006	0.050±0.021
		Reproductive parts	-	-	-	-	0.210±0.062	0.224±0.036	0.243±0.017	0.250±0.024
	Shrub	Leaf	-	-	-	-	0.649±0.015	0.653±0.012	0.654±0.008	0.646±0.014
	Herb	Leaf	1.020±0.360	0.890±0.124	0.890±0.104	0.864±0.120	0.798±0.102	0.782±0.112	0.810±0.141	0.821±0.154

Table 2. Concentration (% ± 1 s.e.) of nutrients in litter fall of different components of the vegetation

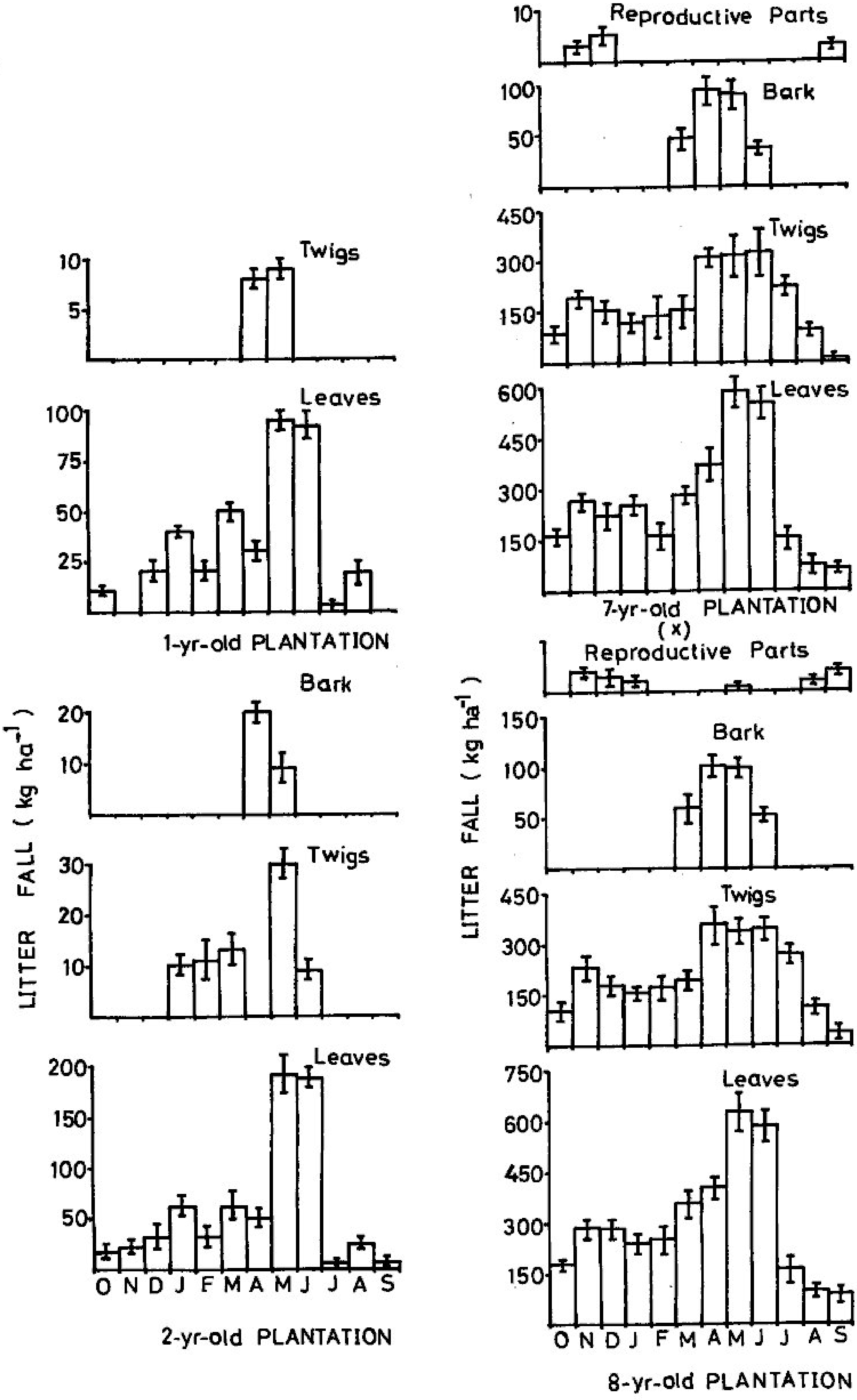

Fig.1. Seasonal pattern *Eucalyptus* plantations. Vertical lines are standard errors of the mean values.

present paper deals with litter fall, nutrient return and leaf litter decomposition in 1 to 8-yr-old *Eucalyptus tereticornis* plantations raised after the clear-cutting of natural sal mixed broad leaf forests and the objectives were (i) to find out the changes in nutrient return from litter with the establishment and development of plantations. (ii) to determine the pattern of leaf litter decomposition with the plantation development and how does the decomposition rate compare with other monocultures and natural forests of the adjacent area? Details of the original vegetation are given in Bargali and Singh (1991) and the startning conditions of all the plantations were the same.

Study sites

All the eight study sites were located between 29°3' and 29°12' N and between 79°20' and 79°23' E at an altitudinal range of 230-280 m in the tarai belt of Central Himalaya. The climate of the tarai belt is subtropical monsoon type with a long dry season from early October to mid June, and a wet season from mid June to early October. The annual average rainfall was 1593 mm (1985-89) of which 86% occurred in mid June to September. The mean monthly temperature ranges from 14.4°C (January) to 31.3° C (June). These data were collected from Pant Nagar which is near to study area. The plantations in this study had 2,000 trees per ha^{-1} which plant to plant and row to row distances of 1.25 and 4 m; respectively. The basal area increased from 0.2 m^2 ha^{-1} to 22.9 m^2 ha^{-1}. Shrub vegetation dominated by *Lantana camara* appeared first in 5-yr-old plantation; its density and basal area also increased with plantation age (Bargali 1990). Herbs were present in all plantations but decreased in density with increase in tree cover and biomass.

Methods

The litter input was measured by placing ten litter traps randomly on the forest floor in each site. Each trap was 50 x 50 cm with 15 cm high wooden sides and fitted with a nylon net bottom. The litter was collected at one month interval during the study period. The litter from each trap was placed in paper beg separated and brought to the laboratory where samples were separated and categorized into different components viz., leaf, wood, bark and reproductive parts. The sampels were oven dried at 60° C to constant weight and weighed and analysed for nutrients. Nitrogen content was determined by K-jel-auto VS-KTP analyzer based on micro-Kjeldahl technique (Peach and Tracey 1956, Misra 1968), P was determined by spectrophotometer and K by flame photometer (Jackson 1958). The nutrient concentration was multiplied by the weight of litter fall to compute the amount of nutrients returned to soil.

Nutrients	Components	Plantation age (Years)							
		1	2	3	4	5	6	7	8
N	Tree								
	-Leaf	2.39	6.30	10.58	18.64	22.32	26.53	29.16	32.57
	-Wood	0.06	0.34	1.71	2.50	4.07	6.53	8.15	9.25
	-Bark	-	0.06	0.12	0.22	0.31	0.42	0.71	0.85
	-Reproductive parts	-	-	-	-	0.03	0.07	0.09	0.13
	Total tree	2.45	6.70	12.41	21.36	26.70	33.55	38.11	42.79
	Shrub	-	-	-	-	1.19	1.85	3.02	3.76
	Herb	59.90	57.60	52.00	46.40	40.90	33.10	31.00	29.10
	Total	62.35	64.30	64.41	67.76	68.79	68.50	72.13	75.65
P	Tree								
	-Leaf	0.21	0.38	0.63	1.13	1.36	1.63	1.79	2.03
	-Wood	0.001	0.01	0.03	0.03	0.07	0.11	0.16	0.18
	-Bark	-	0.001	0.004	0.01	0.01	0.01	0.02	0.02
	-Reproductive parts	-	-	-	-	0.001	0.002	0.003	0.004
	-Total tree	0.21	0.39	0.66	1.17	1.44	1.75	1.97	2.23
	Shrub	-	-	-	-	0.12	0.18	0.29	0.37
	Herb	3.90	3.90	2.70	2.70	2.10	2.00	1.80	1.70
	Total	4.11	4.29	3.36	3.87	3.66	3.93	4.06	4.30
K	Tree								
	-Leaf	1.21	2.19	3.71	6.50	7.89	9.47	10.39	11.55
	-Wood	0.01	0.05	0.23	0.34	0.56	0.91	1.14	1.34
	-Bark	-	0.01	0.02	0.05	0.07	0.09	0.15	0.18
	-Reproductive parts	-	-	-	-	0.01	0.02	0.03	0.04
	-Total tree	1.21	2.25	3.96	6.89	8.53	10.49	11.71	13.10
	Shrub	-	-	-	-	0.60	0.92	1.50	1.85
	Herb	29.40	25.40	23.50	20.20	16.50	14.10	13.40	13.00
	Total	30.61	27.65	27.46	27.09	25.63	25.51	26.61	27.95

Table 3. Amount of nutrient (Kg ha^{-1} yr^{-1}) in litter fall of different components of the vegetation.

Period after placement of bags (days)	Age of plantations (years) 1	2	3	4	5	6	7	8
62	0.10	0.13	0.06	0.05	0.05	0.07	0.06	0.06
121	0.19	0.22	0.23	0.23	0.23	0.16	0.17	0.18
182	0.13	0.15	0.06	0.05	0.06	0.03	0.03	0.02
243	0.65	0.62	0.65	0.62	0.59	0.59	0.60	0.63
304	0.38	0.36	0.39	0.38	0.41	0.43	0.41	0.42
365	0.08	0.08	0.10	0.09	0.09	0.12	0.12	0.09
427	0.08	0.05	0.08	0.12	0.11	0.13	0.13	0.13
487	-	-	0.05	0.05	0.05	0.06	0.06	0.05

Table 4. Rate of decomposition (% day^{-1}) of 1 to 8-yr-old *Eucalyptus leaves.*

Litter decomposition was determined by litter bag technique, which is a direct method of measuring decomposition rate. The fresh leaf litter from each plantation were collected and were air dried. Litter bags of nylon net with 1 mm diameter apertures were used and 5 g of litter samples from each age plantations were kept in separate litter bags. The litter bags were randomly placed on the forest floor of each age plantations in December 1987 in such a manner that they were in contact with soil, care being taken not to disturb forest floor vegetation and forest floor components. From each plantation site three litter bags were recovered at monthly interval. The bags were than placed in individual polyethylene bags for transportation to laboratory. In the laboratory the materials after separating from bags were carefully washed with distilled water to remove soil particles and dried at 60°C to constant weight and weighed.

Results

Litter fall

The total annual tree litter fall ranged from 0.4 to 6.5 t ha^{-1} in 1 and 8-yr-old plantation, respectively (Table 1). The percent contribution of leaf litter fall to the total litter fall declined from 95% in 1-yr-old to about 55% in 8-yr-old plantation. While that of wood (5-39%), bark (3-5%) and reproductive litter fall (0.1-0.3%) to total litter fall increased with the increased age. There was a clearly more litter fall during warm and dry season of the year i. e., March-June than other periods (Fig. 1). Of the total leaf litter fall, 55 to 72% occurred in this season.

Analysis of variance indicated that quantity of litter fall was significantly affected by age, component, months and all their interactions ($P < 0.05$ or 0.01) indicating a differential temporal pattern of litter fall.

Nutrient return

Table 2 shows the concentration of nutrients in litter from different layers (tree + shrub + herb). Concentration of all nutrients was higher in reproductive parts followed by leaf litter, wood litter and bark litter. Shrub and herbaceous components had a greater concentration of all nutrients than tree litter components.

The amounts (Kg ha^{-1} yr^{-1}) of nutrients returned in tree and shrub litter fall increased with age and contrast for herbaceous litter (Table 3).

Decomposition

Although weight loss continued thoroughout the study period, relatively much higher weight loss occurred during 182-243 days in all age plantations (Fig. 2). At the end of 16 months about 96%-98.7% weight loss was observed. In this study the leaf litter placed on 1 and 2-yr-old plantation decomposed at faster rates than in older sites. The rate of decomposition decreased significantly with the increase in plantation age according to the following equation:

$$Y = 0.264 - 0.005\,X \; (r = -0.944,\; P < 0.01)$$

where, Y = rate of decomposition (% day-1) and X = age of plantation (Year).

The rate of decomposition (% day^{-1}) was faster during rainy and summer season than during winter. (Table 4).

To assess the temporal pattern of weight loss the percent weight remaining was regressed against the days elapsed (Table 5). There existed a significant negative relationship between per cent weight remaining and time elapsed for all age plantations. To find out the influence of abiotic factors on weight loss, the monthly weight loss values were regressed against the temperature, rainfall and humidity of respective months (Table 6). The per cent weight loss was significantly correlated ($P < 0.01$) and ($P < 0.05$) with all the above climatic factors. Berg *at al.* 1982 and Berg and Lundmark 1987 have stated that climatic factors govern the decomposition in terrestrial ecosystem.

Discussion

The present values of litter fall (2.79-6.50 t ha^{-1} yr^{-1}) for 4-yr-old to 8-yr-old plantations approach the values reported for other *Eucalyptus* plantations of similar age (Frederick *et al.* 1985). In the adjacent to present study area the ntural forest is *Shorea robusta* and for a relatively young forest stand of *S. robusta* a litter fall values of 6.6 t ha^{-1} yr^{-1} has been reported by Mehra *at al.* (1985) and Mehra and Singh (1985) which is similar to that of present plantations of older ages.

The leaf litter fall value of present study for 7 and 8-yr-old plantations approach the lower limit (6.0-6.3 t ha^{-1} yr^{-1}) for *E. regnans* plantations (Frederick *et al.* 1985).

Age of plantation (years)	Intercept	Slope	Correl. coeff.	SyX	t
1	107.85	-0.268	-0.969	10.88	9.72
2	105.79	-0.267	-0.972	10.31	12.21
3	106.27	-0.241	-0.964	11.89	9.53
4	106.69	-0.237	-0.968	11.03	10.12
5	106.74	-0.234	-0.968	10.92	10.13
6	108.53	-0.233	-0.968	10.87	10.13
7	108.63	-0.234	-0.968	10.87	10.15
8	108.16	-0.234	-0.965	11.34	9.76

Table 5. Relationship between per cent weight remaining of leaf litter (y) and day elapsed (x), ($y = a + bx$). All are significant at $P<0.01$

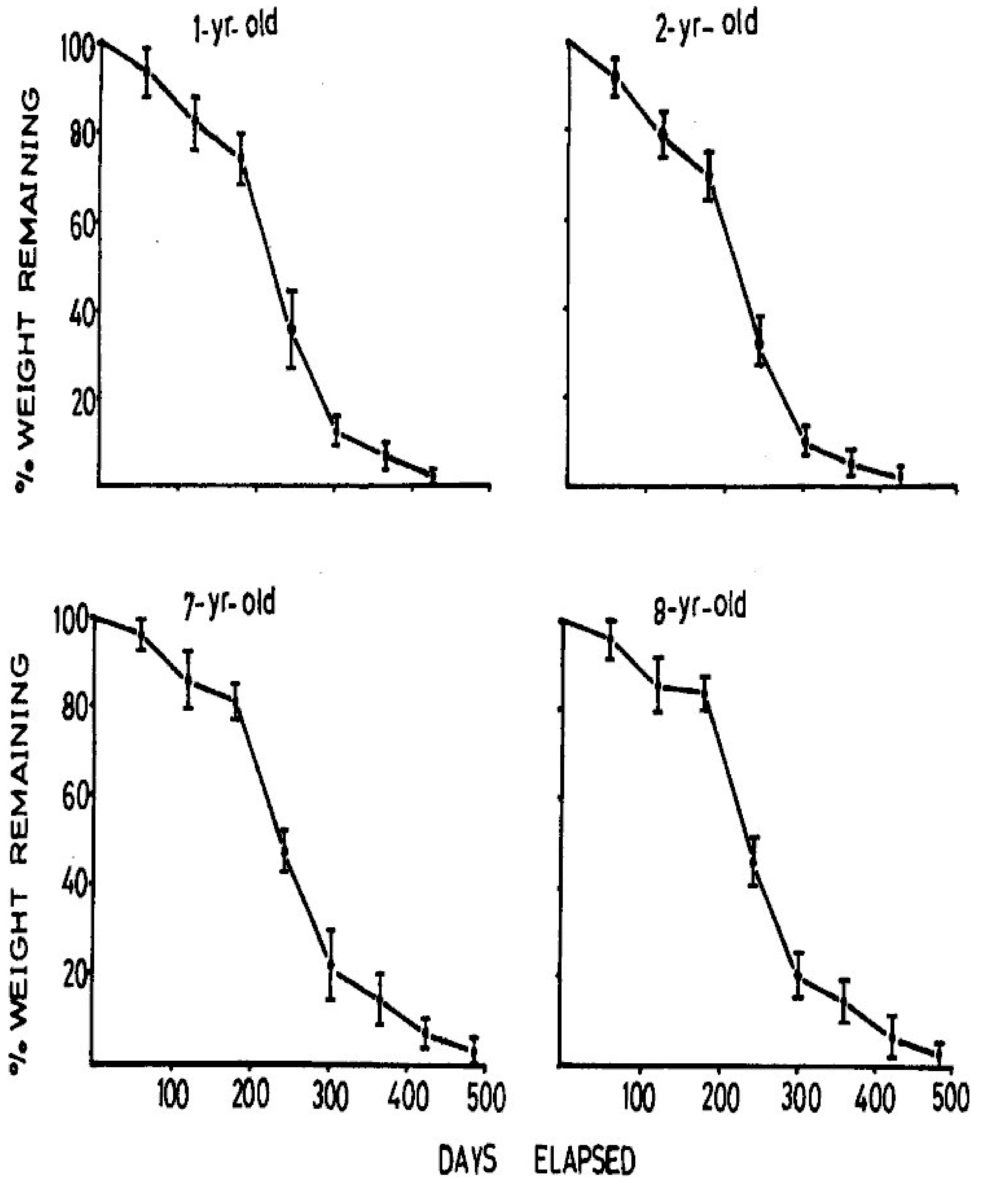

Fig. 2. Percent leaf litter remaining of *Eucalyptus* in 1,2 and 7,8 yr-old plantations.

The annual wood litter fall was 0.02-2.7 t ha-1 in present study. Frederick *et al.* (1985) reported 0.7-4.9 t $ha^{-1} yr^{-1}$ wood litter fall for 4 to 17-yr-old *E.regnans* plantations. The total inputs of nutrients via tree litter fall were: N 2.45-42.79, P 0.21-2.23 and K 1.22-13.1 Kg ha-1yr-1. Turner and Lambert (1983) have reported N 51.05, P 2.07 and K 11.36 Kg $ha^{-1} yr^{-1}$ return via tree litter fall for 27-yr-old E.grandis plantation. Of the nutrient return through litter fall, 85.1-98.8% was through leaf litter fall and 1.2-14.9% through wood litter fall (including twigs + bark + reproductive parts). The nutrient input through leaf litter fall generally accounts for 75-85% and wood litter fall (including flower and fruits) for 10-35% (Klinge and Rodrigues 1968, Bernhard-Reversat 1972), Pandey and Singh (1981).

It has been shown that the liable fractions of litter provide a radially available source of energy for the decomposers. The leaf litter placed at 1 and 2-yr-old plantations decomposed at faster rates than in older sites. Singh *et al.* (1990) have shown that the microbial populations are also related to site conditions and that could be influenced by native leaf litter. The original ecosystem where *Eucalyptus* was planted was rich in decomposers and its influence continued for some time (Bargali 1990). As the time progressed the decomposer fauba possibly became somewhat poorer under the influence of *Eucalyptus* litter. Moreover in young plantations soil moisture, soil nutrients and herbaceous

X vs Y	Age of plantation	Intercept (a)	Slope (b)	Correlation coefficient (r)
R vs WL	1	6.012	0.034	0.978*
	2	9.132	0.021	0.631**
	3	4.645	0.036	0.959*
	4	4.886	0.034	0.952*
	5	4.886	0.034	0.923*
	6	4.802	0.034	0.975*
	7	4.776	0.034	0.975*
	8	4.344	0.036	0.970*
T vs WL	1	-17.627	1.411	0.700**
	2	-16.308	1.352	0.712*
	3	-19.034	1.419	0.645**
	4	-16.076	1.278	0.608**
	5	-16.638	1.298	0.636**
	6	-15.999	1.268	0.625**
	7	-16.194	1.277	0.624**
	8	-16.859	1.307	0.602**
RH vs WL	1	-13.235	0.412	0.417^{ns}
	2	-10.745	0.374	0.402^{ns}
	3	-25.781	0.583	0.543**
	4	-26.576	0.593	0.578**
	5	-26.286	0.587	0.588**
	6	-30.166	0.645	0.652**
	7	-29.132	0.629	0.631**
	8	-32.105	0.675	0.637**

Table 6. Allometric relationship between per cent weight loss (WL) and rainfall (R), temperature (T) and relative humidity (RH), *significant at $P<0.01$, **significant at $P<0.05$, ^{ns}not significant .

ground cover (which are richer in nutrients) were relatively higher and decreased with the increase in plantation age. (Bargali 1990 and Bargali and Singh 1991, Bargali *et al.* 1993). All these may favour decomposition of litter.

Compared to the adjacent *Populus deltoides* plantations of similar age (Lodhiyal 1990) and natural sal *Shorea robusta* forest (Upadhyay and Singh 1989 and Upadhyay *et al.* 1989), the decomposition rates of *Eucalyptus* plantations are lower though both soil and water conditions of sal forest sites are less favourable to plant growth than in the tarai belt (Singh and Singh 1987).

When considering what would be the most important variables regulating the decomposition rates of litter, two principal factors emerge: Climate and site properties (nutrient, moisture, ground cover, etc. in the soil). As in the present plantations the soil moisture, soil nutrients and ground cover (herbaceous vegetation) decreased with the plantation age (Bargali *et al.* 1993), due to the clear-cutting of the natural forest which are the promotors of the decomposition of litter. These two rate regulating factors interact; both are needed in order to predict patterns and rates of decomposition. In conclusion the decrease in decomposition rate with increasing plantation age; suggests that *Eucalyptus* plantations may lead to soil degradation in the present short roatation i. e., 8 year.

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