EVALUATION OF CROPS IN AGROFORESTRY WITH TEAK (*TECTONA GRANDIS*), MAHARUKH (*AILANTHUS EXCELSA*) AND TAMARIND (*TAMARINDUS INDICA*) ON RECLAIMED SALT AFFECTED SOILS

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DAGAR, J.C., SINGH, G. & SINGH, N.T. 1995. Evaluation of crops in agroforestry with teak (*Tectona grandis*), maharukh (*Ailanthus excelsa*) and tamarind (*Tamarindus indica*) on reclaimed salt affected soils. To identify suitable crops for growing in interspaces of six-year-old teak (*Tectona grandis*), maharukh (*Ailanthus excelsa*) and tamarind (*Tamarindus indica*) plantations on reclaimed salt affected soils, various combinations of crops, viz. rice-berseem, rice-wheat, pearl millet-mustard, pearl millet-lentil, and sorghum-gram were examined during *kharif* and *rabi* seasons for two years in 1990-92. There was a reduction in yield of all the crops interplanted in the plantations as compared with the control (outside plantation), but the reduction was minimum with tamarind because of less canopy. Lentil, gram, sorghum, berseem, wheat and rice could be grown successfully with tamarind without much reduction in yield, but with teak only berseem and gram could be grown, while with maharukh only gram could be grown with 25% reduction in yield. All the tree species benefitted by growing all the interspace crops because additional water was made available to them through irrigation. However, with tamarind the advantage of growing rice, wheat, and berseem was minimum as compared to sorghum, lentil and gram. Regression equations were derived to calculate the aerial biomass of trees after harvesting five to eight trees of each species. Annual litter productions with maharukh, teak and tamarind were 8215, 4538 and 3629 kg ha^{-1} respectively and maximum litter was produced from January to April. Nutrient concentrations of P, K, Ca, Mg, Na, Fe, Mn, Zn and Cu in the litter of all plantations are also discussed.

Key words: Agroforestry - *kharif* - *rabi* - waterlogging - sodicity - salinity - alkalinity - vegetation - agro-ecological system - nutrient recycling - crop rotation - litter

DAGAR, J.C., SINGH, G. & SINGH, N.T. 1995. Penilaian tanaman-tanaman dalam perhutanan tani dengan jati (*Tectona grandis*), maharukh (*Ailanthus excelsa*) dan asam jawa (*Tamarindus indica*) pada tanih tebus guna yang dipengaruhi garam. Untuk mengenal pasti tanaman yang sesuai ditanam di ruang antara pokok jati (*Tectona grandis*), maharukh (*Ailanthus excelsa*) dan asam jawa (*Tamarindus indica*) yang berumur enam tahun di ladang-ladang pada tanih tebus guna, pelbagai gabungan tanaman iaitu padi-berseem, padi-wheat, pearl millet-mustard, pearl millet-lentil, dan sorghum-gram dikaji semasa musim *kharif* dan *rabi* selama dua tahun (1990-1992). Terdapat penurunan dalam hasil kesemua tanaman yang ditanam selang di ladang-ladang tersebut berbanding dengan kawalan (di luar ladang), tetapi penurunan ini adalah minimum dengan pokok asam jawa kerana kanopinya kurang. Lentil,gram, sorghum, berseem, gandum dan padi boleh ditanam dengan jayanya dengan pokok asam jawa tanpa banyak penurunan dalam hasil tetapi berseem dan gram boleh ditanam dengan jati, sementara gram sahaja boleh ditanam dengan maharukh dengan penurunan sebanyak 25% dalam hasil. Kesemua spesies pokok tersebut mendapat faedah dengan penanaman selang itu kerana air tambahan melalui pengairan. Bagaimanapun kelebihan menanam padi, gandum dan berseem dengan pokok asam jawa adalah minimum berbanding dengan menanam pokok asam jawa daya sorghum, lentil dan gram. Persamaan-persamaan regresi diperolehi untuk mengira biojisim aerial pokok-pokok selepas menuai lima hingga lapan pokok bagi setiap spesies. Pengeluaran sarap tahunan bagi maharukh, jati dan pokok asam masing-masing ialah 8215, 4538 dan 3629 kg ha^{-1} dan sarap maksimum dikeluarkan dari bulan Januari hingga bulan April. Kepekatan nutrien P, K, Ca, Mg, Na, Fe, Mn, Zn, dan Cu dalam sarap kesemua ladang juga dibincangkan.

Introduction

Of the 329 million ha geographical land area of India, about 175 million ha suffer from varying and progressive degrees of degration through natural or man-made processes. The majority of these lands are treated as waste lands as their productivity is low due to soil based constraints like waterlogging, salinity, sodicity, and sandy, stony or gravey features. Soil salinity and alkalinity have degraded about 8.5 million ha of land in India (Singh 1992). Already a sizeable area exposed to innundation has gone out of cultivation making the landscape devoid of any vegetation except for a few hardy trees like *Prosopis juliflora, Salvadora persica, S. oleoides, Capparis decidua* and *Acacia nilotica*; grasses like *Sporobolus marginatus, Aeleuropus lagopoides* and *Desmostachya pinnata*; and salt tolerant bushes like *Suaeda fruticosa* and *Kochia indica.*

Agroforestry is an option of great promise for use of such lands in view of the growing demand for fuelwood, timber and fodder, and also environmental considerations. Establishment of permanent vegetation cover will stop further degradation of these land resources. Studies at the Central Soil Salinity Research Institute, Karnal during the last decade have been geared up to develop agroforestry systems for optimal use of salt-affected soils. The establishment of tree plantations on these lands is imperative to neutralize the rapidly widening mismatch between demand and supply of wood resources (Swaminathan 1980) and to maintain an agile agro-ecological system. Further more, tree plantations are universally known to result in many beneficial interactions with the surroundings in which they grow. Most efficacious amongst these is the production of litter and nutrient recycling. Litter enriches the soil with organic matter and essential nutrients (Gill & Abrol 1986, Gill *et al.* 1987, Singh *et al.* 1993, Xu *et al.* 1993 a,b). Considering the vast scope that salt affected soils offer for agroforestry, a number of tree species were planted in the Institute Research Farm in 1984. Three of these species were selected for interplanting over two years (1990-91, 1991-92) in different crop rotations to find out the most suitable inter-crops. Investigations were conducted to assess the wood biomass production, litter production and nutrient recycling characteristics in these plantations.

Materials and methods

This study was initiated with three six-year-old plantations of maharukh (*Ailanthus excelsa*) teak (*Tectona grandis*) and tamarind (*Tamarindus indica*) on a reclaimed salt affected soil (Singh *et al.* 1993) of the Central Soil Salinity Research Institute, Karnal (75° 56'N, 29° 29'E), at an altitude of 232 m.s.l. The climate of the area is sub-tropical and semi-arid with an average annual rainfall of *c.* 700 mm, most of which is received from the southwest monsoon between May and October. The temperature follows an upward trend from February onwards until the summer with maxima often exceeding 40 °C in May or June. The total annual evaporation is approximately 2440 mm. The climatic data for the study period are represented in Figure 1. During 1991-92 the annual rainfall at Karnal was 665 mm as compared to an average rainfall of 897 mm between 1981 and 1990. The total open pan evaporation was 1484 mm and the average sunshine hours per day were 7.5. Soils of study area are dark brown to olive brown, sandy loam to clay loam and silty clay loam with slow to moderate permeability. Physico-chemical characteristics of the profiles have been described in detail by Bhumbla *et al.* (1972).

The trees were first planted in 1984 in 6 × 6 m space following the post hole technique described in detail by Gill and Abrol (1986) and Singh *et al.* (1988, 1993). For determining biomass of trees, eight trees of maharukh, six trees of teak, and five trees of tamarind were harvested after measuring their heights and girths. These were segregated into bole (up to the place where branches started), branches (of diameter > 4 cm) and twigs (diameter < 4 cm). Aerial fresh biomass was recorded in the field and pieces of different diameters, after taking their fresh weights, were oven-dried for three days at 80 °C to determine dry biomass. Periodical litter production was measured using wooden traps (each 1 m^2) keeping five traps at random in each plantation. The litter sample from each block of plantation was kept for chemical analysis. These samples were oven-dried after washing with acidulated (0.05 N HCl) water followed by distilled and deionized waters. The samples were digested in diacid mixture of HNO_3 and $HClO_4$ (3:1 ratio). The resultant digest was analysed for P, K, Ca, Mg, Na, Fe, Mn, Zn and Cu following standard analytical procedures (Jackson 1967). Litter of all the species consisted mainly of foliage except in maharukh where the thick petioles were also a part of the litter, particularly from January to April. To identify suitable crops for growing in interspaces of the three plantations the following combinations of crops were used during *kharif* (sown in summer season) and *rabi* (sown in winter) seasons for two years (during 1990-91 and 1991-92):

Kharif season (May to October)	*Rabi* season (November to April)
Rice (*Oryza sativa*)	Berseem (*Trifolium alexandrium*)
Rice (*O. sativa*)	Wheat (*Triticum aestivum*)
Pearl millet (*Pennisetum purpureum*)	Mustard (*Brassica campestris*)
Pearlmillet (*P. purpureum*)	Lentil (*Lens esculenta*)
Sorghum (*Sorghum vulgare*)	Gram (*Cicer arietinum*)

The crops were grown as intercrops, between the rows of plantation trees on 1m wide bunds. Crops were also grown outside the plantations to serve as control. Diameter and height of trees were measured at the initial stage of experiment and after two years.

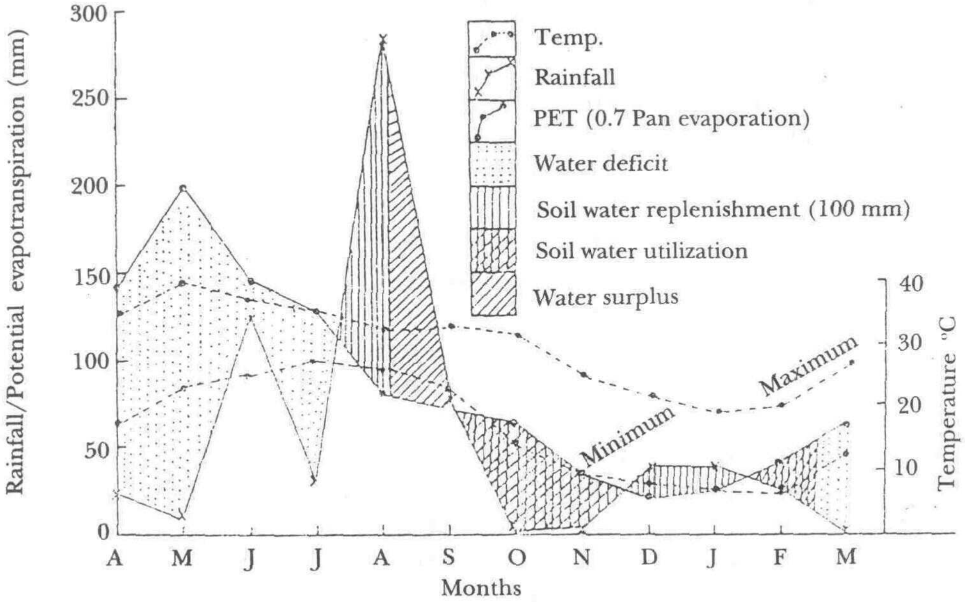

Figure 1. Climatic parameters at CSSRI, Karnal during 1991-92

Results and discussion

Performance of intercrops

The various intercrops planted in the teak, maharukh and teak plantations showed varying degrees of reduction in yields of grain and straw when compared with the controls (Table 1). While the highest reduction (88 %) was observed for the straw dry matter yield of mustard with maharukh, rice showed a consistently high reduction in grain yield (75 - 77 %) with teak and maharukh. The reduction in yield was generally maximum with maharukh, perhaps because of more canopy development. The reduction was minimum with tamarind, where, compared with pearl millet and mustard, lentil, gram, sorghum, berseem wheat and rice are the ideal crops to be planted in the interspaces. Berseem and gram can be reasonably grown with teak while only gram can be grown with maharukh.

Performance of trees with different crops

The trees which were harvested randomly for their biomass ranged from 6.50 to 9.20 m in height and 45 to 73 cm in girth (at breast height) for maharukh, 6.30 to 8.90 m height and 26 to 50 cm girth for teak, and 4.90 to 6.35 m height and 32 to 50 cm girth for tamarind. When a correlation matrix was prepared between various parameters (Table 2), it was found that there was high correlation (r=0.987, 0.956, 0.998, p=0.01) between girth and total biomass of wood. Subsequently, regression

Table 1. Yield and straw biomass (t ha^{-1}) of different crops interplanted with the three tree species (average of two years)

Crop rotation	Control (without plantation)			With teak			With maharukh			With tamarind		
	Grain	Straw		Grain	Straw		Grain	Straw		Grain	Straw	
		Fresh wt.	Dry matter		Fresh wt.	Dry matter		Fresh wt.	Dry matter		Fresh wt.	Dry matter
Rice	5.2	-	17.8	1.3 (75)	-	5.6 (69)	1.2 (77)	-	5.7 (68)	4.2 (19)	-	16.2 (9)
Berseem	-	96.2	12.6	-	68.1 (29)	9.3 (26)	-	40.9 (59)	5.2 (59)	-	81.1 (16)	10.7 (19)
Rice	5.0	-	17.0	1.2 (76)	-	5.5 (68)	1.2 (76)	-	5.8 (66)	4.0 (20)	-	11.3 (34)
Wheat	4.1	-	5.3	2.0 (51)	-	2.1 (60)	0.9 (78)	-	1.3 (75)	3.6 (12)	-	4.3 (19)
Pearl millet (fodder)	-	20.0	4.9	-	8.8 (56)	2.2 (55)	-	12.4 (38)	3.2 (35)	-	15.9 (21)	4.0 (18)
Mustard	2.1	-	7.7	0.9 (57)	-	2.8 (64)	0.5 (76)	-	0.9 (88)	1.1 (48)	-	4.7 (39)
Pearl millet (fodder)	-	20.2	5.0	-	8.6 (57)	2.1 (58)	-	12.6 (38)	3.2 (36)	-	16.0 (31)	4.1 (18)
Lentil	1.6	-	5.2 (50)	0.8 (52)	-	2.5 (69)	0.5 (69)	-	1.6 (6)	1.5 (12)	-	4.6
Sorghum (fodder)	-	13.8	4.0 (73)	-	3.7 (75)	1.0 (70)	-	4.1 (70)	1.2 (70)	-	12.4 (10)	3.6 (10)
Gram	1.6	-	2.7	1.3 (19)	-	2.1 (22)	1.2 (25)	-	2.0 (26)	1.5 (6)	-	2.4 (11)

The values in parentheses are the percentage reductions in yield/biomass over the controls.

equations were derived by using biomass as dependent parameter and girth at breast height (bh) as independent parameter. In teak and tamarind the mean girth at three places was significant; therefore, equations between mean girth and biomass could also be predicted (Table 3).

Table 2. Correlation matrix of maharukh, teak and tamarind plantations

Parameters	Plantations					
	Maharukh					
	a	b	c	d	e	f
a	1.000					
b	0.688	1.000				
c	0.506	0.853	1.000			
d	0.556	0.823	0.987	1.000		
e	0.541	0.715	0.927	0.913	1.000	
f	0.318	0.655	0.921	0.891	0.962	1.000

Critical value (p = 0.5, n = 8) = ± 0.627.

Parameters	Teak					
	a	b	c	d	e	f
a	1.000					
b	- 0.161	1.000				
c	- 0.479	0.681	1.000			
d	- 0.322	0.823	0.956	1.000		
e	- 0.347	0.835	0.918	0.986	1.000	
f	- 0.397	0.858	0.931	0.981	0.967	1.000

Critical value (p = 0.5, n = 6) = ± 0.740.

Parameters	Tamarind					
	a	b	c	d	e	f
a	1.000					
b	0.859	1.000				
c	0.679	0.843	1.000			
d	0.677	0.820	0.998	1.000		
e	0.679	0.811	0.992	0.997	1.000	
f	0.626	0.699	0.954	0.971	0.981	1.000

Critical value (p = 0.5, n = 5) = ± 0.822.

Parameters a = height up to branch (cm); b = total height of the tree (cm); c = girth at breast height; d = mean girth at bottom, middle and top of trunk (cm); e = dry biomass of clear bole (kg); f = total aerial biomass of the tree (kg); n = total number of trees harvested.

As the arable crops were irrigated frequently, trees could get sufficient moisture for their growth. In rice-berseem and rice-wheat rotations the availability of moisture was maximum because both of these crops required more irrigation; therefore, the average increases in growth and girth in maharukh and teak were maximum in these rotations. Prior to the experiment, these trees were facing drought, but within two years of crop rotation there was a large improvement in growth performance. With tamarind, these rotations did not show the same trend probably because of low requirement of water by these trees. Growth performances of pearl millet-lentil, sorghum-gram, and pearl millet-mustard were more outstanding with tamarind as compared to rice-berseem and rice-wheat rotations. In any case, the growth performance of trees under all crop rotations was better than the fallow, without any crop. The increase in dry biomass of trees under different crop sequences was calculated using regression equations of Table 3, using data of girth at breast height in maharukh and mean of girth at three places in teak and tamarind since they were more accurate as shown in Table 2. The trend was the same for growth and girth (Table 4). These results are in line with those of Singh *et al.* (1988, 1993) who conducted experiments in an highly alkaline soil (pH > 10) and found that the *Prosopis juliflora* tree and *Leptochloa fusca* grass combination was a promising agroforestry system for the development of alkaline soils. In this system the grass could produce 45.5 t ha^{-1} green forage in a period of 50 months and improved the growth of *P. juliflora.* In the same experiment, the grass was ploughed after 50 months of growth and fodder crops, viz. berseem (*Trifolium alexandrium*), Persian clover (*T. resupinatum*), lucerne (*Medicago sativa*), and sweet clover (*Melilotus denticulata*) were grown which could produce 21.3, 23.1, 10.3 and 8.0 t ha^{-1} forage respectively. In another experiment, crops in different sequences in association with three species of trees, viz. *Eucalyptus tereticornis, Populus delteoides* and *Acacia nilotica* were planted. Preliminary results showed that after two years *P. delteoides* grew more bulky and taller in association with rice and pigeon-pea. All crop sequences helped the tree growth except in *A. nilotica* where the height and diameter in the control were greater than in the crops (Singh *et al.* 1992) because of its low water requirement like tamarind.

Litter fall and nutrient recycled through litter

Annual litter production of maharukh plantation was higher than that of teak and tamarind plantations probably because in maharukh the leaves were compound and the petioles large, and the entire foliage falls during summer. Total annual litterfalls in maharukh, teak and tamarind were 8215, 4538 and 3629 kg ha^{-1} respectively. In maharukh, the main period of leaf-fall was from December to April (maximum in Januari-February) while in teak it was between February to April and in tamarind it was almost throughout the year (maximum in February to March). The monthly litterfall is shown in Figure 2, but monthly data for more years are required to establish a trend. Gill *et al.* (1987) found a peak in litterfall between November to February in *Eucalyptus tereticornis* plantation and two peaks, a principal peak in winter and a minor one in early summer, in

Table 3. Regression equations between different parameters of the three tree plantations

Parameters	Equations	
Maharukh (n=7)		
Total height vs. total dry biomass	$y = -65.7 + 0.22x_1$	$r = 0.66$*
Girth at breast height vs. total dry biomass	$y = -145.5 + 4.20x_2$	$r = 0.92$***
Girth, mean of 3 places vs. total dry biomass	$y = -124.7 + 3.51x'_2$	$r = 0.89$**
Girth at breast height and total height vs. dry biomass	$y = -136.1 - 0.03x_1 + 4.43x_2$	$r^2 = 0.91$***
Teak (n=5)		
Total height vs. dry biomass	$y = -123.7 + 0.26x_1$	$r = 0.86$*
Girth at breast height (cm) vs. total dry biomass (kg)	$y = -48.5 + 2.96x2$	$r = 0.93$**
Girth mean of 3 places (cm) vs. dry biomass	$y = -58.3 + 2.95x'_2$	$r = 0.98$**
Girth at breast height and total height vs. dry biomass	$y = -111.0 + 0.13x_1 + 2.04x_2$	$r^2 = 0.96$**
Tamarind (n=4)		
Total height vs. biomass	$y = -34.0 + 0.16x_1$	$r = 0.70$ n.s.
Girth at breast height vs. total dry biomass	$y = -128.8 + 4.14x_1$	$r = 0.95$**
Girth, mean of 3 places vs. biomass	$y = -19.3 + 1.92x'_2$	$r = 0.97$**
Girth at breast height and total height vs. biomass	$y = -252.1 - 1.21x_1 + 12.83x_2$	$r^2 = 0.95$**

y = predicted total dry biomass (kg); x_1 = total height (cm); x_2 = girth (cm) at breast height (1.37 m);
x'_2 = girth (cm), mean of 3 places;
n = degree of freedom; *** = significant at 0.1%; ** = significant at 1 %; * = significant at 5%;
n.s. = not significant.

Acacia nilotica plantation. The nutrient concentrations of P, K, Ca, Mg, Fe, Zn and Cu in litter (Table 5) show that the tamarind litter was richest in P, Ca, Fe and Cu, teak litter in Mg, Mn and Zn, and maharukh litter in K. The litterfall in tamarind was less because the tree is slow growing and its canopy had not yet developed properly. The litter values in maharukh and teak were comparable with those of many of the considerably older stands of other species under tropical and temperate conditions (Bray & Gorham 1964, Saito 1981, Kikuzawa *et al.* 1984, Gill *et al.* 1987, Singh *et al.* 1993). Results of this experiment show that growing maharukh and teak on partially reclaimed alkaline soils can ameliorate these soils

Table 4. Performance of the tree species with different crop rotations

Trees	Crop rotation	Average height at start of experiment (m)	Average increase in ht. after 2 years (m)	Average girth at 5 cm ht. at start (cm)	Average increase in girth at 5 cm ht. (cm)	Average girth at 1.37m at start (cm)	Average increase in girth at 1.37 m (cm)	Average increase in dry biomass (kg)
Teak	Rice-berseem	6.49	2.12	48.0	16.2	34.5	21.3	62.8
	Rice-wheat	6.51	2.19	51.2	17.8	33.7	19.3	56.9
	Pearl millet-mustard	6.18	1.92	49.0	14.5	34.7	15.1	48.5
	Pearl millet-lentil	7.12	1.62	48.4	16.6	35.6	18.4	54.3
	Sorghum-gram	6.23	1.67	47.5	14.2	31.4	15.5	45.7
	Fallow	6.33	0.98	50.3	8.8	35.7	11.5	33.9
Maharukh	Rice-berseem	7.11	2.38	75.9	17.2	51.3	24.3	102.1
	Rice-wheat	6.96	2.32	74.2	19.8	48.6	22.1	92.8
	Pearl millet-mustard	7.52	1.92	79.2	18.8	56.4	13.4	56.3
	Pearl millet-lentil	7.84	2.03	81.3	19.0	60.4	15.5	65.1

continued

Table 4 (continued)

	Sorghum-gram	7.32	1.86	77.3	14.0	59.2	13.5	56.7
	Fallow	7.16	1.63	80.1	11.0	55.9	8.0	33.6
Tamarind	Rice-berseem	4.32	0.58	38.6	6.8	24.3	9.4	18.0
	Rice-wheat	4.43	0.56	39.8	8.0	25.1	12.4	23.8
	Pearl millet-mustard	3.93	0.72	29.3	7.1	24.3	8.6	16.5
	Pearl millet-lentil	3.87	0.78	31.8	10.3	21.0	11.7	22.5
	Sorghum-gram	4.37	0.73	37.8	8.8	22.4	11.9	22.8
	Fallow	3.95	0.51	29.6	5.3	22.9	5.5	10.6

and during the initial years rice-berseem, lentil and gram can be grown as intercrops. Many intercrops, viz. lentil, gram, berseem, sorghum and even rice and wheat, may be grown with tamarind during the initial ten years without much reduction in yield.

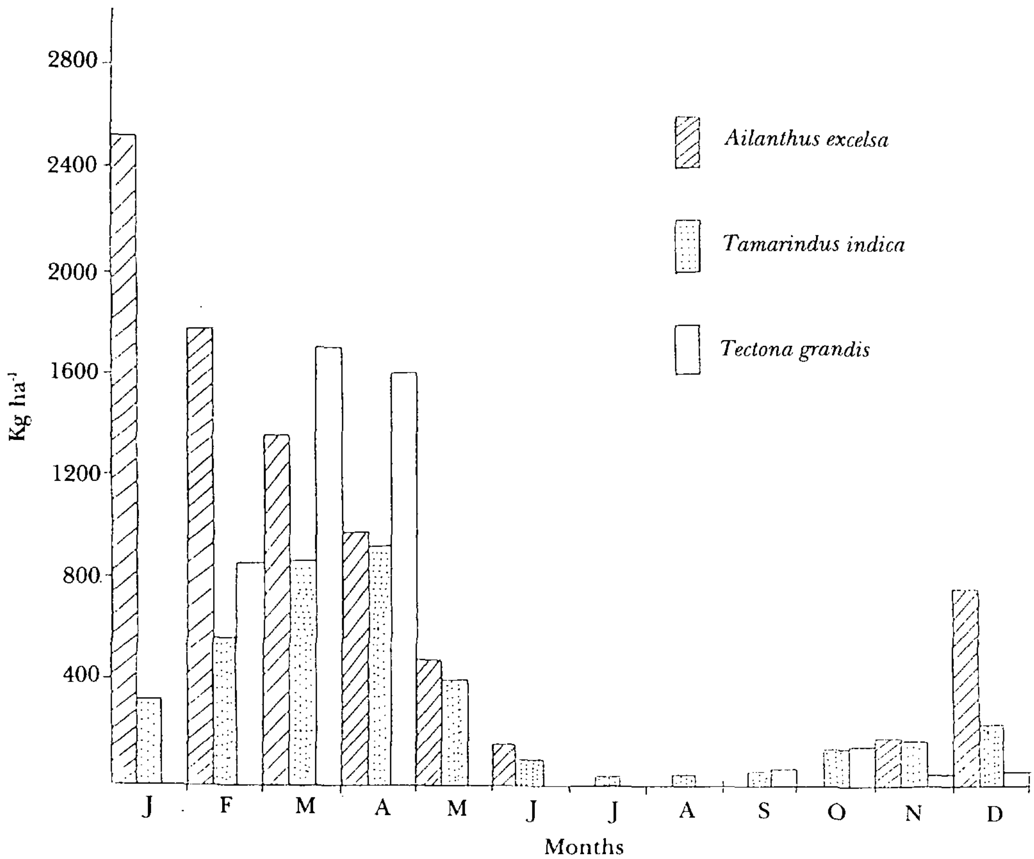

Figure 2. Monthly litterfall with *Ailanthus excelsa*, *Tamarindus indica* and *Tectona grandis*

Table 5. Nutrient composition of leaf litter of the three tree species

Trees	Nutrient composition								
	P	K	Ca	Mg	Na	Fe	Mn	Zn	Cu
	%					ppm			
Maharukh	0.15	1.39	2.40	0.56	0.04	480	90	36	16
Teak	0.14	0.58	2.90	0.74	0.04	380	107	51	51
Tamarind	0.17	0.78	3.15	0.36	0.03	600	47	25	32

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