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Rates of leaf fall and nutrient recycling of shade trees in coffee (*Coffea arabica* L.), cardamom (*Elettaria cardamomum* Maton) and black pepper (*Piper nigrum* L.) production systems of Mudigere, Karnataka

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Abstract

The rates of leaf fall and nutrient addition by different shade trees in coffee (*Coffea arabica*), cardamom (*Elettaria cardamomum*) and black pepper (*Piper nigrum*) production systems were determined at Mudigere (Karnataka). Most trees shed leaves during September to December. Highest leaf shed (4214.5 g m^{-2} $year^{-1}$) was noticed in *Artocarpus integrifolia* followed by *Ficus tjahela* (3976.2 g m^{-2} $year^{-1}$). Nitrogen concentration of the leaves varied from 0.21% (*Dalbergia latifolia)* to 1.89% (*Albizia lebbeck*); phosphorus concentration from 0.01% (*Holigarna arnottiana*) to 0.11% (*Pongamia pinnata*); and potassium concentration from 0.21% (*H. arnottiana*) to 1.52% (*Lagerstroemia lanceolata)*. In coffee production system, *A. integrifolia* recorded highest content of nitrogen (39.19 g m^{-2} $year^{-1}$) while *F. tjahela* recorded higher phosphorus (2.07 g m^{-2} $year^{-1}$) and potassium (34.99 g m^{-2} $year^{-1}$) contents. In cardamom production system, *Erythrina indica* recorded higher contents of nitrogen (25.72 g m^{-2} $year^{-1}$) and phosphorus (1.62 g m^{-2} $year^{-1}$) while *L. lanceolata* contained more potassium (14.11 g m^{-2} $year^{-1}$). In black pepper production system, *Michelia champaca* recorded higher contents of nitrogen (31.11 g m^{-2} $year^{-1}$), phosphorus (3.46 g $m^{-2}$$year^{-1}$) and potassium (29.95 g m^{-2} $year^{-1}$). Species that were rich in nitrogen content had initial lower (< 30) C/N ratio. Lignin content varied from 17.3% to 25.3% and cellulose from 4.4% to 10.1% in various tree species.

Keywords: black pepper, cardamom, coffee, leaf fall, nutrient cycling, shade tree.

Coffee (*Coffea arabica* L.), cardamom (*Elettaria cardamomum* Maton), black pepper (*Piper nigrum* L.) and other plantation crops occupy nearly 60% of the total cropped area (4.11 lakh ha) in the hill zone of Karnataka. Coffee, cardamom and black pepper are sciophytes that need filtered light for their growth and yield. They are commonly cultivated beneath the shade of trees which play a dominant role in recycling of nutrients through their leaves and other parts. Such tree-crop based land use systems are more efficient in maintaining soil fertility than annual cropping systems. Shade tree leaves along with the other resources such as green manures, weeds, loppings, dead wood and coffee wastes have high potential for recycling. Estimates indicate that use of crop residues can provide 7 million tonnes of NPK (Guar & Singh 1994), thereby reducing the gap of required nutrients to 5 million tonnes in India. Biomass regeneration and utilization as a source of

organic input has been a feasible approach towards upgrading productivity of land and crop. The present study is an effort towards quantifying the rates of leaf fall from some common shade/support trees present in major sciophytic production systems in the hill zone of Karnataka and characterization of the same based on major nutrients.

The study was conducted at the Zonal Agricultural Research Station, Mudigere (Karnataka), during 2002 and 2003. Coffee, cardamom and black pepper production systems were considered for the study. The study site is located 978 m above MSL ($13^0 7'29''$N latitude and $75^0 37'$E longitude). The soils belonged to sandy red loam lateritic type having acidic pH (5.6–6.2) and high organic carbon (1.0%–1.4%), low phosphorous (up to 11.8 kg ha^{-1}) and medium potassium (305–425 kg ha^{-1}) contents. In each production system naturally grown individual shade trees were chosen from mixed tree species to collect the fallen leaves. In all, 19 different shade tree species were chosen and for each species, 4 trees were selected as replicates. A shade tree in each production system was marked and physical characters like, crown spread (E–W, N–S) and its circumference at 1.5 m height were recorded. For collection of shed leaves, 1 m^2 area was marked beneath each tree depending on the tree canopy width in all the four directions. In a few cases, depending on the canopy and direction, the collection area varied up to 5 m^2. The leaves of the different tree species were collected at 10 days interval for 1 year. The collected leaves were dried initially under shade and then in hot air oven at 70^0 C till it attained a constant weight. The data on dry weight was expressed in terms of g m^{-2} $year^{-1}$ at four month intervals namely, October to January, February to May and June to September. For estimation of nutrients, the leaf samples were washed externally and dried before powdering. The following standard procedures were adopted for analysis of the nutrients in the laboratory: Kjehl Tech method for nitrogen; spectrophotometry for phosphorus; and flame photometry for potassium. The total nutrient content was determined by following the standard formula: per cent content x dry weight. Further, single replicate leaf samples of different shade trees were analyzed for lignin (refluxing with acid detergents method) and cellulose (acetolysis method) contents following standard procedures.

Canopy spread

Among the trees, *Artocarpus integrifolia* Lamk. had maximum radial growth (153 cm) and lowest was recorded in *Grevillea robusta* A. Cunn. (98.5 cm). *A. hirsutus* Lamk. had maximum east-west spread (936 cm) and *Erythrina indica* Lamk. had maximum north–south spread (1218.4 cm) (Table 1). It should be noted that the distances that are being maintained with neighbouring trees along with lopping periods largely determine the crop canopy.

Leaf fall rates

The crop management procedures adopted, season, location of the tree and slope to a higher degree influenced the amount of leaf shed by different tree species. Among the different trees in coffee production system, highest leaf shed was recorded in *A. integrifolia* (4214.5 g m^{-2} $year^{-1}$) and the least in *Terminalia bellarica* (Gaerty) Roxb. (1810.3 g m^{-2} $year^{-1}$). In cardamom system, *Syzygium cumini* (Linn.) Benth (1900.9 g m^{-2} $year^{-1}$) recorded highest leaf fall. *Michelia champaca* Linn. (3840.2 g m^{-2} $year^{-1}$) followed by *G. robusta* (1854.8 g m^{-2} $year^{-1}$) recorded highest leaf fall in black pepper production system (Table 2). Leaf size and canopy size of trees largely determined the amount of leaf fall. Canopy size of a tree depended on requirement of light intensity for the primary crop. The number of trees per unit area and the pruning followed were the prime considerations for leaf fall rates. Leaf fall was dominant in winter wherein the difference between maximum and minimum temperature prevailed to a greater extent in this season. Higher retention of leaves on the trees during summer is always advocated as it provided good shade for the main crop. However, *Ficus tjahela* Linn., *Bischofia javanica* Bl. and *Lagerstroemia lanceolata* Wall ex Clarke

Table 1. Crown spread and tree girth of shade tree species

Species	Crown spread (cm)		Tree girth* (cm)
	E-W	N-S	
Coffee production system			
Artocarpus hirsutus	936.0	700.2	140.0
Ficus tjahela	672.7	830.8	113.2
Holigarna arnottiana	596.7	859.6	168.9
Artocarpus integrifolia	846.6	669.4	153.0
Ficus mysorensis	570.3	853.6	115.4
Gmelina arborea	520.3	771.5	116.7
Bischofia javanica	718.9	830.6	156.9
Terminalia bellerica	732.7	881.2	126.1
SD	156.3	147.3	24.8
Cardamom production system			
Terminalia arjuna	607.3	457.3	112.3
Erythrina indica	596.3	1218.4	90.5
Syzygium cumini	765.3	737.1	133.9
Lagerstroemia lanceolata	667.9	656.4	113.2
Albizia lebbeck	493.4	538.5	102.1
Ficus tsiela	692.3	566.1	133.8
Dalbergia latifolia	638.7	688.4	140.4
SD	219.2	176.3	21.9
Black pepper production system			
Pongamia pinnata	466.3	598.6	98.7
Cedrella toona	507.3	607.3	118.8
Grevillea robusta	509.8	458.9	95.6
Michelia champaca	458.8	599.0	136.7
SD	120.9	212.1	25.5
Mean	631.4	711.7	124.5
SD	130.6	179.7	21.6

*At breast height (1.5 m)

shed leaves in larger proportion during February to May. Earlier studies at Balehonnur (Karnataka) indicated that in coffee plantations, shade tree leaf litter fall was around 10,000 kg ha^{-1} $year^{-1}$ (Jayarama *et al.* 1996). The loping of different tree species in coffee plantations yielded 5.0–12.5 t ha^{-1} $year^{-1}$ (Kang *et al.* 1990). Different tree species in cardamom plantations contributed 5–8 t ha^{-1} dry leaves in Kodagu (Karnataka) (Korikanthimath *et al*. 1996). Litter production of 12.69 t ha^{-1} was recorded in casuarina plantations and it followed a unimodel distribution (Jamaludheen & Kumar 1999). In large cardamom plantations, maximum litter and crop residue was obtained with Ainus + cardamom system (Sharma *et al*. 1997).

Nutrient concentration

Nutrient concentration of various tree species in different production systems is more related to the individual species that takes up nutrients from deeper layers in that system and also crop management over the years. In the present study exceptionally higher levels of N were recorded in the fallen leaves of *Albizia lebbeck* (Linn.) Benth (1.83%), *Pongamia pinnata* (Linn.) Pierce (1.67%) and *E. indica* (1.57%). Being members of Fabaceae both uptake and retention of N were possibly high in these species. Compared to them, *A. integrifolia* and *F. tjahela* had moderate level of nitrogen (around 0.9%). Interestingly, species from a similar family varied in nutrient concentrating ability except in Fabaceae. The leaves of *P. pinnata* (0.10%), *E. indica* (0.10%)

Table 2. Seasonal leaf fall rates of shade tree species

Species	Leaf fall rate (g m^{-2} $year^{-1}$)			
	June–Sept.	Oct.–Jan.	Feb.–May	Total
Coffee production system				
Artocarpus hirsutus	1064.7	1157.3	864.1	3086.1
Ficus tjahela	827.0	1530.8	1618.4	3976.2
Holigarna arnottiana	184.9	1673.6	1384.9	3243.4
Artocarpus integrifolia	1633.0	1706.5	875.0	4214.5
Ficus mysorensis	1117.4	1688.7	198.3	3004.8
Gmelina arborea	360.4	693.7	883.7	1937.8
Bischofia javanica	739.2	1107.0	1657.1	3503.4
Terminalia bellerica	264.3	611.9	934.1	1810.3
Mean	773.8	1271.2	1051.9	
SD	496.0	447.4	483.4	
Cardamom production system				
Terminalia arjuna	288.6	774.1	811.6	1874.3
Erythrina indica	517.7	503.0	617.7	1638.4
Syzygium cumini	182.5	600.7	1117.7	1900.9
Lagerstroemia lanceolata	130.9	310.5	535.2	979.6
Albizia lebbeck	97.2	405.2	406.2	908.6
Ficus tsiela	261.3	500.4	470.7	1232.4
Dalbergia latifolia	180.5	319.1	455.8	955.4
Mean	236.9	487.5	630.7	
SD	140.8	164.2	253.7	
Black pepper production system				
Pongamia pinnata	228.6	450.5	458.4	1137.5
Cedrella toona	133.7	395.6	399.4	928.7
Grevillea robusta	404.3	1163.0	287.5	1854.8
Michelia champaca	714.3	1989.0	1136.9	3840.2
Mean	370.3	999.5	570.6	
SD	255.3	746.5	384.2	
Grand mean	491.1	925.3	795.4	2212.0
SD	420.8	555.6	433.5	1139.2

and *M. champaca* (0.09%) were rich in phosphorous. Trees with higher nitrogen showed a moderate level of phosphorous also. Similarly, the leaves of *L. lanceolata* (1.44%) recorded higher concentration of potassium (Table 3). No definite trend was obtained in nutrient concentration of the leaves with respect to season. Nitrogen concentration of the leaves varied from 0.21% in *Dalbergia latifolia* Roxb. to 1.89% for *A. lebbeck* during June–September. Phosphorous content varied from 0.01% in *Holigarna arnottiana* Hook to 0.11% in *P. pinnata* again during June–September. Potassium content varied from 0.21% in *H. arnottiana* during February–May to 1.52% in *L. lanceolata* during October–January.

The calculated value for nutrient uptake by different species which indicates the renewable capacity of nutrients or inputs if it is properly utilized, was also determined (Table 4). In coffee production system, *A. integrifolia* recorded highest amount of nitrogen (39.19 g m^{-2} $year^{-1}$), *F. tjahela* recorded higher phosphorous (2.07 g m^{-2} $year^{-1}$) and potassium (34.99 g m^{-2} $year^{-1}$) contents. In cardamom production system, *E. indica* recorded higher amount of nitrogen (25.72 g m^{-2} $year^{-1}$) and phosphorous (1.62 g m^{-2} $year^{-1}$). *L. lanceolata* was observed to contain more potassium (14.11 g m^{-2} $year^{-1}$). In black pepper production system, *M. champaca* recorded higher content of nitrogen (31.11 g m^{-2} $year^{-1}$), phos-

Table 3. Nitrogen, phosphorus and potassium concentration of leaves of shade tree species

Species	N concentration (%)				P concentration (%)				K concentration (%)			
	June–Sept.	Oct.–Jan.	Feb.–May	Mean	June–Sept.	Oct.–Jan.	Feb.–May	Mean	June–Sept.	Oct.–Jan.	Feb.–May	Mean
Coffee production system												
Artocarpus hirsutus	1.06	0.78	0.62	0.82	0.062	0.058	0.064	0.061	0.48	0.40	0.35	0.41
Ficus tjahela	0.98	0.87	0.91	0.92	0.058	0.053	0.046	0.052	0.92	0.85	0.87	0.88
Holigarna arnottiana	0.50	0.27	0.37	0.38	0.011	0.019	0.021	0.017	0.22	0.24	0.21	0.22
Artocarpus integrifolia	1.07	0.90	0.82	0.93	0.042	0.037	0.034	0.038	0.71	0.69	0.64	0.68
Ficus mysorensis	0.45	0.52	0.50	0.49	0.058	0.057	0.056	0.057	0.83	0.84	0.82	0.83
Gmelina arborea	0.80	0.69	0.73	0.74	0.048	0.040	0.034	0.041	0.78	0.68	0.67	0.71
Bischofia javanica	0.48	0.41	0.45	0.42	0.034	0.030	0.028	0.031	0.48	0.52	0.50	0.49
Terminalia bellerica	0.72	0.64	0.68	0.68	0.023	0.021	0.025	0.023	0.39	0.42	0.36	0.38
Terminalia arjuna	0.59	0.59	0.65	0.61	0.045	0.042	0.036	0.041	0.71	0.68	0.44	0.61
SD	0.26	0.22	0.19	0.22	0.018	0.016	0.015	0.016	0.25	0.22	0.24	0.23
Cardamom production system												
Erythrina indica	1.68	1.51	1.52	1.57	0.103	0.100	0.095	0.099	0.52	0.47	0.45	0.48
Syzygium cumini	0.75	0.81	0.78	0.78	0.085	0.078	0.080	0.081	0.25	0.25	0.25	0.25
Lagerstroemia lanceolata	0.90	0.81	0.75	0.82	0.035	0.031	0.025	0.030	1.49	1.52	1.31	1.44
Albizia lebbeck	1.89	1.85	1.75	1.83	0.018	0.020	0.019	0.019	0.94	0.90	0.80	0.88
Ficus tsiela	0.61	0.52	0.52	0.55	0.060	0.050	0.046	0.052	0.82	0.68	0.60	0.70
Dalbergia latifolia	0.21	0.23	0.24	0.23	0.087	0.77	0.70	0.078	0.45	0.35	0.34	0.38
SD	0.61	0.53	0.55	0.55	0.031	0.029	0.029	0.028	0.41	0.42	0.39	0.38
Black pepper production system												
Pongamia pinnata	1.58	1.87	1.56	1.67	0.113	0.098	0.098	0.103	0.68	0.64	0.54	0.62
Cedrella toona	0.42	0.32	0.31	0.35	0.053	0.054	0.061	0.056	1.05	1.01	0.94	1.00
Grevillea robusta	0.82	0.81	0.73	0.79	0.060	0.050	0.053	0.051	0.45	0.38	0.37	0.40
Michelia champaca	0.88	0.79	0.76	0.81	0.101	0.089	0.080	0.090	0.84	0.80	0.70	0.78
SD	0.48	0.66	0.52	0.51	0.023	0.024	0.010	0.023	0.25	0.26	0.24	0.24

Table 4. Nutrient inputs through leaf fall of shade tree species

Species	Dry matter (g m^{-2} $year^{-1}$)	N	P	K
		(g m^{-2} $year^{-1}$)		
Coffee production system				
Artocarpus hirsutus	3086.1	25.31	1.88	12.66
Ficus tjahela	3976.2	36.58	2.07	34.99
Holigarna arnottiana	3243.4	12.32	0.55	07.14
Artocarpus integrifolia	4214.5	39.19	1.60	28.66
Ficus mysorensis	3004.8	14.72	1.71	24.94
Gmelina arborea	1937.8	14.34	0.79	13.76
Bischofia javanica	3503.4	14.71	1.09	17.17
Terminalia bellarica	1810.3	12.31	0.42	06.88
SD		11.12	0.63	10.27
Cardamom production system				
Terminalia arjuna	1874.3	11.43	0.77	11.43
Erythrina indica	1638.4	25.72	1.62	07.86
Syzygium cumini	1900.9	14.83	1.54	04.75
Lagerstroemia lanceolata	979.6	08.03	0.29	14.11
Albizia lebbeck	908.6	16.63	0.17	08.00
Ficus tsiela	1232.4	06.78	0.64	08.63
Dalbergia latifolia	955.4	02.20	0.75	03.63
SD		7.71	0.56	3.61
Black pepper production system				
Pongamia pinnata	1137.5	19.00	1.17	07.05
Cedrella toona	928.7	03.25	0.52	9.29
Grevillea robusta	1854.8	14.65	0.95	7.42
Michelia champaca	3842.2	31.11	3.46	29.95
SD		11.51	1.32	11.06
Grand mean		17.01	1.16	13.56
SD		9.86	0.67	9.06

phorous (3.46 g m^{-2} $year^{-1}$) and potassium (29.95 g m^{-2} $year^{-1}$). Quantification of removal of nutrients helps in further composting of these leaves either to get rich content of a nutrient or combinations. Jayarama *et al.* (1996) reported that mixture of shade trees in coffee plantations returned around 40–60 kg N, 13–30 kg P and 40–60 kg K ha^{-1}. In the decomposed cashew leaf litter, organic carbon content ranged from 0.7% to 1.61%, total nitrogen from 0.18% to 0.25%, available phosphorous from 0.13% to 0.23% and potassium from 0.29% to 0.40% (Sharma *et al.* 1997). A huge quantity of organic matter was reported to be recycled through the leaves and branches of intercrops like black pepper and cinnamon in arecanut and coconut gardens adding 20 kg N, 15 kg P and 14 kg K per hectare *in situ* (George & Kumar 1988; Pramanik *et al.* 1995).

The contents of lignin and cellulose and L/N and C/N ratios of leaves are also equally important for further degradation of leaves. The lignin content varied from 17.3% to 25.3% with L/N ratio varying from 12 to 48. The initial content of the cellulose varied from 4.4% to 10.1% (Table 5). Higher content of lignin demands more of phosphorous based substances along with other essential additives such as cow dung for early decomposition (Babitha, 1998). In the present study, many species had wider C/N ratio. Those rich in nitrogen content had initial lower C/N ratio (< 30) and species belonging to Fabaceae recorded the lowest ratio.

Table 5. Lignin, cellulose, C/N and L/N contents of shade tree species*

Species	Lignin (%)	Cellulose (%)	C/N	L/N
Coffee production system				
Artocarpus hirsutus	24.8	7.8	57.8	26.8
Ficus tjahela	23.4	8.3	25.4	27.4
Holigarna arnottiana	20.8	7.8	54.7	56.7
Artocarpus integrifolia	25.3	9.3	27.2	27.9
Ficus mysorensis	17.3	8.9	35.3	32.8
Gmelina arborea	20.4	8.1	27.6	26.9
Bischofia javanica	17.3	7.3	41.9	40.8
Terminalia bellarica	18.6	5.9	14.8	29.7
Cardamom production system				
Terminalia arjuna	21.2	5.5	34.8	34.8
Erythrina indica	18.9	4.3	12.1	12.8
Syzygium cumini	19.4	7.4	24.9	25.9
Lagerstroemia lanceolata	19.4	4.4	23.7	24.8
Albizia lebbeck	20.4	7.7	11.1	11.8
Ficus tsiela	18.9	5.8	78.6	18.7
Dalbergia latifolia	19.9	8.3	86.5	48.9
Black pepper production system				
Pongamia pinnata	18.4	6.6	11.0	10.9
Cedrella toona	18.7	8.9	96.8	24.8
Grevillea robusta	21.2	7.5	26.8	26.9
Michelia champaca	25.3	10.1	34.1	32.5

*Data from single replication

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