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Litters effect on soil physicochemical and biological processes

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ABSTRACT

The present study was carried out during 2016-17 to 2018-19 at All India Coordinated Research Project on Agroforestry under Dr DBSKKV, Dapoli, Maharashtra on Assessment of decomposition dynamics, microbial community and soil fertility under different trees in Alfisol. The 10 years old six tree species, viz. *Gmelina arborea*, *Terminalia tomentosa*, *Acacia mangium*, *Gliricidia sepium*, *Acacia auriculiformis* and *Millettia pinnata* blocks were framed in a randomized block design with four replications. Significantly (P>0.05) build-up of soil fertility, microbial community and enzymes assay were found due to incorporation of *Gliricidia sepium* and *Millettia pinnata* litters and also develops bio-stability in soil which helps to maintain soil fertility. The decompositions, 0-87.35% (weight loss) were recorded and overall decomposition dynamics of litters species in soil trend was, viz. T_4>T_6>T_2>R_1>T_3>T_5. Significantly higher improvement in microbial C: N ratio of soil was recorded by *Gliricidia sepium* (9.14) and *Millettia pinnata* (8.99). The higher microbial communities (bacteria, actinomycetes, fungi) and enzyme assay (dehydrogenase, acid and alkaline phosphatase activities) were recorded by *Gliricidia sepium* followed by *Millettia pinnata* which helps for developing biological fertility of soil. Most of the trees are nitrogen fixing species, the higher development and restoring of soil fertility by indigenous *Gliricidia sepium* and *Millettia pinnata* species and these species could be used to more suitable for looking block plantation, bund plantation, alley cropping, development of agroforestry and subsequently could be used as a source of nutrients by directly or *in-situ* litter decomposition in soil in a Tropical Zone.

Key words: CO_2 evolution, C:N Ratio, Hydraulic conductivity, Phosphatase, Weight loss

Production potential of litter biomass by restoration of trees, enrichment of nutritious forest species and its management practices is primarily aimed at running to the basic needs of food, fuel, fodder and timber besides, helping the farmer in increasing sustainable production, particularly from marginal agricultural land as well as by utilizing these species as a source of nutrients for development of soil health and stabilization of ecosystem. The amount of litter-fall could be modified through pruning management quantity as well as quality of litter could be affected by land management practices (Gawali 2014). Litter decomposition can be considered to be driven by the stoichiometry of substrates and microbial demands for resources with maximal rates of decomposition observed when the ratios of supplies of nutrients to microbes match their demands (Craine *et al*. 2007). In Konkan region, average annual rainfall is near about 3500 mm and steep slopping land configurations. Most of the soils are in medium acidic nature. Due to the high rainfall, maximum nutrient losses through leaching and causes severe erosion ultimately soil becomes degraded (Meshram *et al*. 2016). Therefore, developing soil fertility by plantation of nutritious and multipurpose tree species and also development of agroforestry systems might be more helpful for Konkan region farmers to mitigate their soil problems and getting optimum return by adopting different such types of trees species. Considering that there is an increasing need of nutrients demand in soil, reforest, block plantation, bund plantation, alley cropping, as a source of nutrients, etc. in a tropical zone of the Konkan region of Maharashtra. The present study focuses on decomposition dynamics, microbial community and soil fertility under different agro forest trees in Alfisol (Lateritic soil). *Acacia auriculiformis, Acacia mangium, Gliricidia sepium, Gmelina arborea, Millettia pinnata* and *Terminalia tomentosa,* a hardy tree species studied under this investigation these are major tree species (indigenous) found in Konkan agro climatic condition. By using such types forest trees leaf litters can helps in development of soil carbon and restoring soil fertility in lateritic acidic soils of Konkan region.

MATERIALS AND METHODS

The experiment was conducted at Dr BSKKV, Dapoli, Maharashtra during 2016-19. The experimental soil is characterized by reddish colour, Lateritic type of Alfisols, particularly Kaolinitic, hyperthermic family of Typic Haplustalf. The 10 years old six tree species blocks were selected and framed in a randomized block design (RBD)

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with four replications. The *in-situ* incorporation of forest litters species comprises, viz. T_1-*Gmelina arborea*, T_2-*Terminalia tomentosa*, T_3-*Acacia mangium*, T_4-*Gliricidia sepium*, T_5-*Acacia auriculiformis,* T_6-*Millettia pinnata* for three years experimentation.

Incorporation of leaf litters in in-situ decomposition in soil and laboratory analysis: *In-situ* litter decomposition in soil by using litter bag technique and its decomposition rate was calculated on the basis of mass loss rate per month wise (Xiong *et al*. 2008); % Weight loss per month = (Weight loss during the measured month/initial weight of litter) × 100]

The soil samples were collected from the place of decomposed leaf litter bags contaminated soil for further physico-chemical and biological analysis. A representative portion of each soil samples was collected from the 0-30 cm depth of initial and litter contaminated soil site and it was air dried, powdered and passed through <2 mm sieve for determination of physico-chemical properties. Electrical conductivity (EC), soil reaction (*p*H), organic carbon (OC), available NPKS were determined by Jackson (1973). Bacteria, fungi and actinomycetes were determined by serial dilution plate technique (Dhingra and Sinclair 1993). Soil microbial biomass carbon (SMBC) and nitrogen (SMBN) were determined by using chloroform fumigation technique (Brooks *et al.* 1985). CO_2 evolution of soil was determined by alkali trap method (Anderson (1982). Phosphomonoesterases (Acid and alkaline phosphatase) activity in soil determines the enzymatic hydrolysis of p-nitrophenyl phosphate to p-nitrophenol which was extracted by $CaCl_2$–NaOH solution (Tabatabai and Bremner 1969). Dehydrogenase enzyme activity in soil (Klein *et al.* 1971) was determined by triphenylformazan (TPF) produced by the reduction of 2,3,5-triphenyl tetrazolium chloride (TTC). In addition, bulk density, maximum water holding capacity (MWHC) and hydraulic conductivity of soil were determined by standard methods as described by Jackson (1973). The experimental data was analyzed by DBSKKVSTAT software and used guideline as given by Panse and Sukhatme (1985).

RESULTS AND DISCUSSION

Decomposition dynamics: The 3 years experimentation (Table 1) on enrichment of forest trees leaf litter in soil was found to be significant differences (P<0.05) in all the month wise weight loss (0-87.35%) and release of soil CO_2 (62.66-157.29 mg/100 g soil) in different species during *in-situ* decomposition of leaf litter in forest bio-diverse field condition over a period (240 DAI). The *Gliricidia sepium* recorded the maximum weight loss (87.35%) and CO_2 evolution (157.29 mg/100 g soil) at every month and highest % weight loss at 240 DAI (after 8 month) which were found to be at par with *Millettia pinnata* than other litter species. Whereas, the lowest decomposing weight loss (70.45%) was recorded by the *Acacia auriculiformis* at 240 DAI, it might be due to literally high amount of lignin and cellulose content in this species ultimately less decomposition in soil (Chapman *et al.* 2003). The decomposition (weight loss %)

Table 1 Weight loss of litter, CO_2 evolution and physicochemical properties of soil (3 years pooled data)

Treatment	Weight loss (%)		CO_2 evolution (mg /100g Soil)		Bulk density (Mg/m^3)		Maximum water holding capacity (%)		Hydraulic conductivity (cm/hr)		pH		EC (dS/m)		Organic carbon (%)	
	30 DAI	up to 240 DAI	0 DAI	up to 240 DAI	Before start	Pooled	Before start	Pooled	Before start	Pooled	Before start	Pooled	Before start	Pooled	Before start	Pooled
T_1- *Gmelina arborea*	8.40	75.49	69.53	148.34	1.49	1.47	42.28	44.60	10.42	13.11	5.35	5.49	0.09	0.13	1.76	1.88
T_2-*Terminalia tomentosa*	8.84	78.01	71.62	149.30	1.50	1.46	42.44	45.52	10.23	13.52	5.31	5.65	0.10	0.15	1.78	1.89
T_3- *Acacia mangium*	6.67	71.09	65.31	145.37	1.52	1.49	40.42	43.68	9.86	12.16	5.28	5.33	0.09	0.07	1.74	1.79
T_4- *Gliricidia sepium*	10.76	87.35	75.77	157.29	1.48	1.42	43.31	48.36	12.63	15.82	5.39	5.79	0.13	0.18	1.84	1.93
T_5-*A. auriculiformis*	6.48	70.45	62.66	143.86	1.54	1.50	39.29	42.87	8.97	10.81	5.26	5.30	0.08	0.10	1.68	1.78
T_6- *Millettia pinnata*	10.35	84.12	73.26	153.78	1.49	1.43	43.44	47.37	12.18	15.40	5.36	5.72	0.12	0.16	1.82	1.92
Mean	8.58	77.75	69.69	149.66	1.50	1.46	41.86	45.40	10.71	13.47	5.33	5.55	0.10	0.13	1.77	1.86
SE±	0.07	0.61	0.75	0.56	0.019	0.007	0.72	0.28	0.24	0.13	0.07	0.033	0.002	0.0017	0.03	0.008
CD (P= 0.05)	0.22	1.86	2.26	1.70	NS	0.022	2.19	0.84	0.74	0.40	NS	0.099	0.006	0.0052	NS	0.024
CV (%)	1.73	1.58	2.15	0.75	2.65	1.00	3.47	1.24	4.60	1.99	2.63	1.19	2.63	2.68	4.29	0.82
Initial value	-		-		1.55		38.97		8.22		5.27		0.08		1.65	

Parenthesis: Days after incorporation (DAI) trend, viz. T_4>T_6>T_2>R_1>T_3>T_5 was recorded (Table 1). The rate of decomposition was less during initial period that is up to 150 DAI but there after the decomposition rate was increased. This might be due to during initial period June to September were heavy rainfall which leads to low respiration rate but after October to March there was increase in temperature and optimum moisture % level of soil which increases higher respiration rate and microbial community may lead to higher decomposition rate Martinez *et al.* (2013).

Physical environment of soil: Incorporation of trees leaf litter at 240 DAI were observed significantly improvement in bulk density (1.42 Mg/m^3), maximum water holding capacity (48.36 cm/hr) and hydraulic conductivity (15.82 cm/hr) by *Gliricidia sepium* followed by *Millettia pinnata* litter contaminated soil over its initial status of soil which were found at par with each other (Table 1). Whereas, less improvement in bulk density of soil was recorded in *Acacia auriculiformis* and *Acacia mangium* litter contaminated soil due to high compactions rate and less aggregations comparably to other. The addition of highest amount of litter and carbon build-up in the soil helps to improve water stable aggregate in soil and microspores ultimately improved bulk density, water holding capacity and infiltration rate of soil (Kim *et al.* 2010).

Chemical properties of soil: Regarding the fertility status, soil reaction (*p*H 5.79 & 5.72), electrical conductivity (EC 0.18 & 0.16 dS/m), soil organic carbon (OC 1.93 & 1.92 %), available N (389.91 & 384.06 kg/ha), P_2O_5 (15.82 & 13.50 kg/ha), K_2O (362.32 & 352.34 kg/ha), SO_4 (33.37 & 32.68 kg/ha) were significantly noticed maximum by *Gliricidia sepium* followed by *Millettia pinnata* litter

Table 2 Effect of forest leaf litter on chemical and microbial properties of soil (3 years pooled data)

Treatment	Available N (kg/ha)		Available P_2O_5 (kg/ha)		Available K_2O (kg/ha)		Available SO_4 (kg/ha)		Bacteria (CFU × 10^4 /g soil)		Fungi (CFU × 10^4 /g soil)		Actinomycetes (CFU × 10^4 /g soil)	
	Before start	Pooled	Before start	Pooled	Before start	Pooled	Before start	Pooled	Before start	Pooled	Before start	Pooled	Before start	Pooled
T_1	353.30	363.60	15.16	17.14	280.35	311.62	23.30	27.88	88.66	128.17	10.01	15.49	49.07	79.56
T_2	328.53	359.01	12.43	16.73	284.47	315.85	23.54	28.27	82.27	130.33	10.73	16.63	50.79	77.86
T_3	313.55	345.00	11.35	15.25	275.11	293.56	22.50	24.82	77.86	117.95	8.14	14.70	45.52	70.53
T_4	373.40	389.91	15.82	19.06	330.34	362.32	25.75	33.37	92.15	142.96	12.44	21.38	56.30	91.34
T_5	319.37	344.43	13.04	14.18	271.13	288.32	20.37	23.52	68.75	101.13	7.70	14.14	41.00	67.67
T_6	354.01	384.06	13.50	18.50	328.14	352.34	24.09	32.68	92.08	138.26	12.06	20.60	55.18	86.96
Mean	340.36	364.33	13.55	16.81	294.92	320.67	23.26	28.42	83.63	126.47	10.18	17.15	49.64	78.99
SE±	6.72	1.62	0.21	0.19	5.50	2.31	0.54	0.23	1.63	1.92	0.22	0.21	0.60	1.02
CD (P= 0.05)	20.25	4.91	0.65	0.57	16.58	6.97	1.61	0.68	4.93	5.78	0.66	0.63	1.80	3.07
CV (%)	3.94	0.89	3.21	2.26	3.71	1.44	4.59	1.58	88.66	128.17	10.01	15.49	49.07	79.56
Initial value	305.19		11.17		268.24		21.30		62.30		6.84		36.71	

Table 3 Effect of forest leaf litter on enzyme activities and microbial C:N ratio of soil (3 years pooled data)

Treatment	DHA (µg TPF /g soil /24 hr)		Acid phosphatase (µg p-NP /g soil/hr)		Alkaline phosphatase (µg p-NP /g soil/hr)		SMBC (µg/g)		SMBN (µg/g)		Microbial C : N ratio	
	Before start	Pooled	Before start	Pooled	Before start	Pooled	Before start	Pooled	Before start	Pooled	Before start	Pooled
T_1	372.06	423.71	77.45	95.08	218.07	266.88	840.33	1048.85	105.86	116.72	7.95	8.99
T_2	376.40	425.64	79.47	95.97	221.00	265.68	932.96	1047.27	107.29	116.60	8.70	8.98
T_3	349.26	376.30	68.17	91.39	212.80	245.43	756.96	954.05	92.98	104.42	8.15	9.14
T_4	402.13	455.16	82.94	101.43	241.66	288.02	1087.32	1341.54	120.95	153.08	9.00	8.76
T_5	344.27	372.60	67.70	89.29	180.58	201.44	726.60	941.67	89.10	102.58	8.17	9.18
T_6	397.99	446.53	80.01	100.09	232.98	283.90	1029.39	1306.41	117.62	146.33	8.76	8.93
Mean	373.68	416.65	75.96	95.54	217.85	258.56	895.59	1118.07	105.63	123.29	8.45	9.07
SE±	7.54	4.43	1.53	0.59	3.77	1.72	20.01	14.73	1.60	1.07	-	0.14
CD (P= 0.05)	22.74	13.35	4.62	1.78	11.37	5.18	60.32	44.40	4.82	3.23	-	0.42
CV (%)	4.03	2.13	4.03	1.24	3.46	1.33	4.46	2.66	3.03	1.74	-	3.12
Initial value	340.02		61.47		176.24		703.64		75.39		9.33	

Parenthesis, Dehydrogenase enzyme activity (DHA), Soil microbial biomass carbon (SMBC), Soil microbial biomass nitrogen, Microbial carbon: nitrogen ratio of soil (SMBN).

contaminated soil, while the less improvement was recorded in *Acacia auriculiformis* (Table 1, 2). Significantly highest nutrient availability in incorporated leaf litter soil could be attributed to the phenomenon of phytoremediation effect caused due to addition of litter residue in the form of organic matter and also leads to increases the soil *p*H and capacity to neutralizing levels particularly in acid soil condition particularly in Alfisols (Meshram *et al*. 2016).

Biological properties soil: The results provided further evidence that 3 years experimentation on bacterial, actinomycetes and fungi populations as well as dehydrogenase, acid and alkaline phosphatase enzymes activities in soil were significantly ($P<0.05$) influenced by *Gliricidia sepium* and *Millettia pinnata* litter contaminated soil over its before start and initial status of soil (Table 2, 3). It might be due to the application of organic matter through leaf litters with proved better helping for the multiplication of microbial populations and enzyme activities in soil (Rejsek 2000, Meshram *et al*. 2016).

Significantly higher SMBC (1341.54 and 1306.41 µg/g) and SMBN (153.08 and 146.33 µg/g) were observed by *Gliricidia sepium* and *Millettia pinnata* litter contaminated soil over its initial status of soil. The lowest soil microbial biomass C and N were noted by *Acacia auriculiformis*. While, the incorporation of leaf litters bag filled either understory or litter is of paramount importance to maintain a large amount of microbial biomass carbon, nitrogen and microbial C:N ratio of soil (Xiong *et al*. 2008). The maximum improvement in microbial C:N ratio (8.76 and 8.93) by *Gliricidia sepium* and *Millettia pinnata* litter contaminated soil than other litter incorporated species (Table 3). When CO_2 is released via decomposition the C:N ratio of the organic matter decreases, and the microbial demand for mineral nitrogen is decreased. Whether nitrogen is mineralized or immobilized depends on the carbon to nitrogen ratio (C:N ratio) of the plant residues. When the C:N ratio falls below about 25:1 further decomposition results in simultaneous mineralization of nitrogen which is in excess to that required by the microbial population (Xiaodong *et al.* 2009).

It can be concluded that the decomposition of *Gliricidia sepium* and *Millettia pinnata* leaf litter over 240 DAI periods is useful for improving the physical, chemical and biological fertility of soil under bio-diverse condition in lateritic acid Alfisols. The decomposition and improved soil fertility by incorporation of different forest trees leaf litter in soil trend, viz. $T_4>T_6>T_2>R_1>T_3>T_5$ was observed. While, the higher microbial C:N ratio of soil was recorded by *Gliricidia sepium* and *Millettia pinnata* which helps determining carbon and nitrogen mineralization in soil for future key development of soil fertility. In this study, most of the trees are nitrogen fixing species, the higher development of soil fertility by *Gliricidia sepium* and *Millettia pinnata* could be used to more suitable for looking block plantation, bund plantation, alley cropping, development of agroforestry, respectively and subsequently from these easily decomposed nutritious litter sources can be used as a source of nutrients by directly or in-situ litter decomposition for easily availability of nutrient in acid soil.

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