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SOIL MICROFLORA AND BIOLOGICAL ACTIVITIES IN THE RHIZOSPHERES AND ROOT REGIONS OF COCONUT-BASED MULTISTOREYED CROPPING AND COCONUT MONOCROPPING SYSTEMS

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Summary—Microflora, enzyme activities, microbial biomass, C and N mineralization in the rhizosphere and root region soils of coconut-based multistoreyed cropping (pepper, cacao and pineapple) and coconut monocropping systems were studied. The rhizospheres of the different crops had greater numbers of microflora than non-rhizosphere soils. There were fewer bacteria and fungi in the root region soils of coconut monocrop as compared to multistoreyed cropping system. The microflora, enzyme activities, C and N mineralization decreased with soil depth. Urease, dehydrogenase and phosphatase activities showed variable trends in the root regions and rhizospheres of the different crops. The microbial biomass in the root region soil was highest in the coconut and cacao of the multistoreyed cropping system. The organic C, total N, P and K were higher in the root region soils of multistoreyed cropping system than in the coconut monocropping system.

INTRODUCTION

Coconut (*Cocos nucifera* L.) is generally grown in India, as a crop by small and marginal farmers. The average size of a holding is as low as 0.22 ha and *ca* 98% of the holdings are less than 2 ha (Thampan, 1976). One feasible way to increase the farm income is to introduce compatible annual and perennial crops in the interspaces between the coconut palms. Coconut is planted at spacings of 7.5 m × 7.5 m. The lateral spread of coconut roots is no further than 2 m from the bole (75% roots) and their vertical distribution is from 0 to 120 cm depth (Kushwah *et al.*, 1973). To evaluate various possible crop combinations, the concept of multistoreyed cropping was introduced (Nelliat *et al.*, 1974; Nair, 1977). Crops having different stature (canopy size) and rooting patterns were selected to have compatible combinations. The soil microflora has been studied for coconut monocrop and some coconut-based crops by Radha and Menon (1954), Garcia and Valera (1963), Nair and Subba Rao (1977) and Potty *et al.* (1977) but such studies did not include coconut-based multistoreyed cropping systems consisting of pepper, cacao and pineapple. We investigated and measured the microflora, enzyme activities; microbial biomass, C and N mineralization and fertility of soils of multistoreyed cropping and monocropping systems.

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MATERIALS AND METHODS

Site and soil

The coconut-based multistoreyed cropping system with black pepper, cacao and pineapple was initiated in a 20 yr old garden during 1972. The coconut palms had been planted with 7.5 × 7.5 m spacing. Black pepper (*Piper nigrum* L.) was trained to grow on the coconut trunks and allowed to develop its canopy to a height of 8 m. The number of cacao plants in double-hedge planting was 600 ha^{-1}. Pineapple (3500) suckers were planted in the alleys not occupied by cacao. All the crops received recommended doses of fertilizer in two split applications, March and September (Coconut–500 g N, 320 g P_2O_5, 1200 g K_2O $palm^{-1}$ $year^{-1}$; cacao and pepper—100 g N, 40 g P_2O_5, 140 g K_2O $plant^{-1}$ or $Vine^{-1}$ $year^{-1}$; pineapple—14.3 g N, 5.7 g P_2O_5, 17.2 g K_2O $plant^{-1}$ $year^{-1}$). The plots were irrigated to field capacity during the dry months. The soils are sandy loams with low water holding capacities (WHC; 29–33%) low in organic C (0.38%) and total N (0.032%). The pH of the soils ranged from 5.0 to 5.4.

Collection of samples

Samples were collected from the rhizosphere and root regions of coconut, cacao and pineapple of multistoreyed cropping and coconut monocropping systems in October 1983.

Rhizosphere soil

The roots were carefully removed from the block of soil with minimal damage to the roots. Then the roots were gently shaken to remove the soil clumps and cut into 2.5 cm pieces using a sterile scalpel and transferred to polythene bags.

Non-rhizosphere soil

This was collected from the interspaces of coconut, cacao, multistoreyed cropping and coconut monocrop plot (five samples each).

Root region soil

The root region soils were collected from the root zones of various crops depending on the root spread. Using a soil auger, core samples were collected from three depths viz., 0–25, 26–50 and 51–100 cm. Soils were collected from four locations around the plant to obtain a composite sample in each case. In coconut, root region soils were collected 60 cm from the bole of the palm. The cacao and pineapple soils were collected 50 and 25 cm respectively from the base of plants. Three samples each were collected and all the samples were stored in polythene bags at 4°C for 2 weeks.

Soil biological analysis

The rhizosphere and root region microflora were counted by dilution plating (Timonin, 1940; Nair and Subba Rao, 1977). For the enumeration of rhizosphere microflora, 20 root pieces with adhering soil was transferred to a 250 ml flask containing 100 ml sterile water. After thorough shaking suitable dilutions were used. Total bacteria, fungi and actinomycetes populations were counted using soil extract agar, Martin's rose Bengal agar and Kuster's agar respectively. The numbers were expressed on a dry weight soil basis.

Soil biomass was determined using the chloroform fumigation technique (Jenkinson and Powlson, 1976) and the biomass C and N were calculated (Jenkinson and Ladd, 1981). The soil urease activity was assayed as described by Pancholy and Rice (1973) except that the evolved ammonia was estimated by the Nessler reaction (Jackson, 1973). A modified 2,3,5-triphenyl tetrazolium chloride (TTC), reduction procedure (Casida *et al.*, 1964) was used to determine dehydrogenase activity. Phosphatase activity was assayed according to Tabatabai and Bremner (1969).

Air-dried soils, 50 g in 350 ml capacity glucose drip bottles at 60% WHC were incubated with a vial containing 10 ml of 1 N NaOH and the C mineralization for the root region soils was estimated by the amount of CO_2 evolved at different times during 60 days at 30 ± 2°C (Pramer and Schmidt, 1964). Native C mineralization in soil as well as that due to cellulose (0.5%) addition was estimated (in duplicate). N mineralization was determined according to Stanford and Smith (1973). Ammonia (Jackson, 1973), nitrite (Bremner, 1965) and nitrate (Jackson, 1973) were determined after 4 weeks at 30 ± 2°C and later every 2 weeks up to 10 weeks.

Soil chemical analyses

Organic C, total N, total and available P, total and available K and pH were determined (Black, 1965).

RESULTS

The numbers of microorganisms counted in the rhizospheres and root regions of the coconut-based multistoreyed cropping and coconut monocropping systems are shown in Table 1. Bacteria (other than actinomycetes) were more abundant in the rhizospheres of the various crops than the respective root region soils. Among the crops the rhizosphere of cacao and pineapple had the highest numbers of

Table 1. Numbers of microorganisms in the root regions and rhizospheres of coconut multistoreyed cropping (MS) and monocropping systems

Crop	Soil depth (cm)	Root region microflora[a] g^{-1} soil			Rhizosphere microflora[b] g^{-1} soil		
		Bacteria (10^6)	Fungi (10^3)	Actinomycetes (10^4)	Bacteria (10^6)	Fungi (10^3)	Actinomycetes (10^4)
Coconut	0–25	5.0 ± 0.4	32.3 ± 3.4	13.0 ± 2.0	17.4 ± 2.9	11.5 ± 1.6	1.0 ± 0.2
	26–50	3.0 ± 0.6	24.4 ± 2.1	4.0 ± 1.0			
	51–100	1.2 ± 0.3	18.7 ± 4.7	6.0 ± 2.0			
Cacao	0–25	1.5 ± 0.2	42.6 ± 6.5	8.0 ± 3.0	24.2 ± 6.2	15.5 ± 2.8	1.0 ± 0.2
	26–50	1.3 ± 0.0	24.3 ± 2.4	8.0 ± 4.0			
	51–100	0.3 ± 0.0	16.1 ± 2.7	10.0 ± 5.0			
Pineapple (MS)	0–25	1.6 ± 0.3	26.7 ± 4.0	19.0 ± 5.0	20.4 ± 2.7	11.6 ± 0.6	0.8 ± 0.1
	26–50	0.8 ± 0.4	20.5 ± 4.5	32.0 ± 9.0			
Coconut–cacao (interspace)	0–25	0.9 + 0.1	21.2 + 3.5	22.0 + 4.0			
	26–50	0.8 ± 0.1	17.3 ± 2.6	11.0 ± 3.0			
	51–100	0.2 ± 0.1	8.7 ± 2.1	10.0 ± 0.5			
Coconut (monocropping)	0–25	0.8 ± 0.2	13.7 ± 3.0	37.0 ± 2.0	14.9 ± 2.8	10.8 ± 1.2	0.4 ± 0.1
	26–50	0.5 ± 0.1	14.4 ± 2.0	40.0 ± 6.0			
	51–100	0.2 ± 0.1	6.7 ± 0.7	17.0 ± 2.0			
LSD (0.05)							
Crop		3.8	4.9	0.6	5.1	3.1	0.5
Depth		3.0	3.8	0.5			
Crop × depth Interaction		6.7	8.5	1.1			

[a]Average of three replications ± SE.
[b]Average of five replications ± SE.

Table 2. Soil enzyme activities in the root regions and rhizospheres of multistoreyed cropping (MS) and monocropping systems in coconut

Crop	Soil depth	Root region[a]			Rhizosphere[b]			
						Dehydrogenase		
		Urease	Dehydrogenase	Phosphatase	Urease	Without glucose	With glucose	Phosphatase
Coconut (MS)	0–25	3.5 ± 0.3	2.4 ± 0.4	138.0 ± 6.4	6.5 ± 0.3	2.1 ± 0.1	4.7 ± 0.2	131.7 ± 11.7
	26–50	0.7 ± 0.1	1.4 ± 0.2	70.0 ± 5.4				
	51–100	0.8 ± 0.1	ND	35.0 ± 3.8				
Cacao (MS)	0–25	1.4 ± 0.4	2.9 ± 0.3	102.0 ± 6.4	6.4 ± 0.7	2.1 ± 0.1	3.7 ± 0.3	86.7 ± 10.9
	26–50	0.9 ± 0.2	1.7 ± 0.4	51.0 ± 3.6				
	51–100	0.6 ± 0.1	ND	19.6 ± 2.1				
Pineapple (MS)	0–25	1.5 ± 0.4	2.5 ± 0.1	112.0 ± 35	6.2 ± 0.2	2.0 ± 0.1	3.7 ± 0.3	94.3 ± 9.1
	26–50	0.9 ± 0.3	1.3 ± 0.4	45.8 ± 4.5				
	51–100	ND	ND	15.6 ± 2.2				
Coconut (monocropping)	0–25	3.2 ± 0.2	2.9 ± 0.1	69.3 ± 3.0	5.4 ± 0.3	2.8 ± 0.1	4.0 ± 0.2	133.7 ± 5.5
	26–50	2.5 ± 0.3	1.5 ± 0.1	54.3 ± 3.0				
	51–100	0.9 ± 0.1	ND	26.5 ± 1.6				
LSD (0.05)								
Crop		0.4	0.3	3.4	1.0	0.3	0.8	41.2
Depth		0.3	0.2	2.9				
Crop × depth		0.7	0.4	5.8				

[a]Average of three replications ± SE.
[b]Average of five replications ± SE.
Urease, μg NH_4 formed g^{-1} soil h^{-1}.
Dehydrogenase, μg formazon formed g^{-1} soil h^{-1}.
Phosphatase, μg P-nitrophenol g^{-1} soil h^{-1}.

Table 3. C and N mineralization in coconut multistoreyed cropping (MS) and coconut monocropping systems *in vitro*[a]

Crop	Soil depth (cm)	C mineralization (mg 100 g^{-1} soil)		N mineralization (mg 100 g^{-1} soil)		
		Native C	Cellulose (0.5%)	NH_4–N	NO_3–N	Total N
Coconut (MS)	0–25	32.4 ± 3.6	100.0 ± 8.7	0.19	4.0	4.18
	25–50	26.4 ± 2.1	77.4 ± 4.0	0.43	2.9	3.28
	51–100	20.0 ± 1.2	58.8 ± 4.6	0.45	2.9	3.31
Cacao (MS)	0–25	33.6 ± 4.5	144.0 ± 5.3	0.43	5.3	5.68
	26–50	32.4 ± 3.7	68.4 ± 3.9	0.32	5.0	5.32
	51–100	27.4 ± 1.5	48.5 ± 4.0	0.38	2.8	3.17
Pineapple (MS)	0–25	64.2 ± 6.2	115.8 ± 4.6	0.28	6.8	7.05
	26–50	35.4 ± 4.8	81.7 ± 4.7	0.28	3.7	3.95
Coconut + cacao	0–25	22.8 ± 2.6	144.4 ± 5.3	0.51	4.4	4.94
	26–50	18.6 ± 1.5	59.9 ± 4.6	0.33	3.4	3.74
	51–100	15.6 ± 1.3	36.6 ± 5.6	0.26	3.0	3.23
Coconut monocropping	0–25	29.4 ± 0.9	120.5 ± 5.6	0.18	4.6	4.81
	26–50	21.6 ± 1.3	55.8 ± 3.9	0.10	4.9	4.98
	51–100	18.3 ± 1.2	38.4 ± 5.7	0.08	3.3	3.37
Coconut monocropping interspace	0–25	12.0 + 1.4	63.4 + 6.6	0.16	4.4	4.60
	26–50	19.8 ± 1.2	75.8 ± 4.8	0.11	3.1	3.26
	51–100	18.0 ± 1.1	61.4 ± 3.3	0.08	3.0	3.05
LSD (0.05)						
Crop		4.7	6.2	0.01	0.0	
Depth		3.3	4.8	0.01	0.1	
Crop × depth		8.1	11.8	0.02	0.3	

[a]Average of three replications ± SE.

bacteria. The bacteria and fungi were significantly less in the root region and rhizosphere of coconut monocropping when compared to coconut and the other crops in the multistoreyed cropping system. The actinomycetes were more abundant in the root region. The microflora decreased with depth and the counts were least at 51–100 cm depth.

Urease was more active in the rhizospheres than in the root regions of all crops (Table 2) whereas dehydrogenase was slightly more active in the root region soils of the multistoreyed cropping system than in the monocropping system. Phosphatase was not very active in the root region of coconut under monocropping. The addition of glucose increased the activity of dehydrogenase. The activities of urease and phosphatase decreased with soil depth.

C was more actively mineralised in the surface layers (0–25 cm) of the root region soils of coconut, cacao and pineapple of the multistoreyed cropping system (Table 3). The highest rate of C mineralization was recorded in the root region of pineapple. There was no significant difference in C mineralization between the multistoreyed cropping and monocropping systems. Cellulose (0.5%) addition to soil increased the C mineralization rate by from 3- to 4-fold in all soils. Higher concentrations of NH_4–N was found in the root region soils of cacao and pineapple and coconut–cacao interspaces (Table 3). The NO_3–N concentration was also higher in cacao and pineapple soils. However, between coconut in the multistoreyed and in the monocropping there was no differences in the concentrations of NH_4–N during N mineralization. There was little C or N mineralization in the interspace soils of the coconut monocropping systems.

Higher microbial biomass C and N were observed in coconut and cacao soils in the multistoreyed cropping system and lower biomass C and N were recorded in coconut monocropping systems (Table 4). The data on soil chemical analyses are presented in Table 5. The organic C, total N, total P and total K concentrations were greater at all depths in the soils of the multistoreyed cropping system. Soil pH, organic C, total N and P decreased with soil depth in the root region soils of all crops.

DISCUSSION

The general decrease in the soil enzyme activities (urease and phosphatase) in the 26–50 cm and 51–100 cm soil depths can be attributed to microflora, soil pH, organic C, total N and P contents of the soil in both the systems. Tarafdar *et al.* (1981) reported a positive significant correlation in soil urease and

Table 4. Soil biomass C and N in the root region of coconut based multistoreyed (MS) cropping and coconut monocropping systems[a]

Crop	Biomass C (μg C g^{-1} soil)		Biomass N (μg N g^{-1} soil)
	0–10 days	10–20 days	0–10 days
Coconut (MS)	166.4 ± 25.2	37.8 ± 9.6	189.9 ± 24.5
Cacao (MS)	250.0 ± 45.7	49.0 ± 5.6	211.2 ± 18.6
Pineapple (MS)	142.8 ± 31.5	32.5 ± 6.2	142.5 ± 22.8
Coconut (monocrop)	147.9 ± 36.4	30.1 ± 8.4	132.6 ± 32.0
LSD (0.05)	96.5	25.1	89.3

[a]Average of five replications ± SE.

Table 5. Soil chemical analyses in the root region of coconut–cacao–pepper–pineapple cropping (MS) and coconut monocropping systems[a]

Crop	Soil depth (cm)	pH	Organic C (%)	Total N (%)	K Total (%)	K Available ($\mu g\ g^{-1}$)	Potash Total (%)	Potash Available ($\mu g\ g^{-1}$)
Coconut (MS)	0–25	5.2	1.0	0.09	High	25.8	0.21	121.5
	26–50	4.6	0.5	0.05	0.72	22.0	0.25	89.5
	51–100	4.3	0.5	0.05	0.68	8.6	0.28	79.0
Cacao (MS)	0–25	5.3	0.7	0.07	0.80	19.8	0.15	51.5
	26–50	4.7	0.6	0.06	0.55	6.4	0.21	34.5
	51–100	4.4	0.4	0.04	0.07	1.0	0.23	31.0
Pineapple (MS)	0–25	5.0	0.6	0.06	0.07	14.4	0.19	31.0
	26–50	4.3	0.6	0.05	0.09	11.2	0.15	33.5
Coconut monocropping	0–25	5.2	0.5	0.05	0.07	17.5	0.14	31.0
	26–50	4.5	0.4	0.04	0.03	4.2	0.18	13.5
	51–100	4.3	0.3	0.04	0.04	4.5	0.18	21.0

[a]Average of three replications.

alkaline phosphatase activities with organic C, fungal and bacterial population in jute soil. Further, the type of vegetation has been reported to influence the soil urease activity at different depths (Hoult and McGarity, 1986).

The addition of farmyard manure and wheat straw have been reported to increase the rate the CO_2-evolution (Debnath and Hajra, 1972). Similarly in the present investigations, the addition of C source, cellulose increased the carbon mineralization by 3- to 4-fold as compared to the native C mineralization. A close relationship between the total N content and the amount of organic N formed has been reported (Vlassak, 1970). The decrease in C and N mineralization with depth could be due to the lower organic C and N content in the soils. A beneficial interaction was observed in coconut–cacao mixed cropping with improved organic C and other soil fertility factor (Nelliat *et al.*, 1979). The mixed cropping of cacao with coconut increased the microbiological activities and it was attributed to higher organic matter in soil due to periodic shadding of leaves and pruning of cacao (Nair and Subba Rao, 1977). Similar conditions existed in the multistoreyed cropping system also and these might have favoured the increased microflora and biological activities. Microbial biomass has been shown to increase with the addition of energy sources (Nannipieri *et al.*, 1983).

In our study the coconut-based multistoreyed-cropping system soil is under zero tillage, where as in the coconut monocropping system, the soil is ploughed every year. Doran (1980) reported higher aerobic and facultative aerobic bacteria in two surface soil under zero tillage as compared to surface-ploughed soils. The phosphatase and dehydrogenase activities and organic C in the surface of the zero-tillage soil was also significantly higher than those observed in the surface ploughed soils. Similarly in our investigation, the higher microflora, biological activities and organic C in the coconut-based multistoreyed-cropping system can be due to zero tillage as compared to the coconut monocropping soil, which was tilled. The productivity of coconut palms increased in the multistoreyed cropping system as compared to the pre-experimental yield (Nelliat and Shama Bhat, 1979). The additional synergistic effect of an increase in the yield of coconut palm is an excellent example of "non-monetary input" in crop production. The greater biological and fertility factors in the multistoreyed cropping system could favour higher productivity indicating the beneficial effect of growing pepper, cacao and pineapple as compatible crops with coconut.

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