Rainfall interception in arecanut based cropping system

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The partitioning of rain water into throughfall, stem flow and interception loss when passing through plant canopies depends on properties of the respective plant species, such as leaf area and branch angles. In multistoried cropping system or high density cropping system, the presence of different plant species may consequently result in a mosaic of situations with respect to quantity and quality of water inputs into the soil. As these processes influence not only the water availability for the plants, but also water infiltration and nutrient leaching, the understanding of plant effects on the repartitioning of rain water may help in the optimization of land use systems and management practices. The arecanut based cropping system (ABCS) has a closed canopy with component crops like arecanut, cocoa and clove. The mean height of arecanut is 10 m with an LAI of 2.44, leaf area of 22 m^2 and canopy area of 11.2 m^2 (Balasimha, 2004). The mean height of cocoa is estimated at 4 m and LAI varies from 1.5 to 6.0 (Balasimha, 2002).

Precipitation is an important source of nutrient input to the plant ecosystem and the transfer of nutrients to soil is achieved by throughfall and stem flow. These components contain nutrients from incident rainfall and leaching of nutrient substances from plant tissues, which is important as small but significant amount of nutrients could be reaching the soil. Boyer (1973) found that throughfall represented an important source of nutrients with recycling of Ca, Mg and K to the soil in the order of 38, 33 and 113 kg ha^{-1} $year^{-1}$, respectively in cocoa ecosystem in Africa. At Bahia, Brazil, the studies indicated that the throughfall and leaf fall constitute the most important nutrient recycling processes in the cocoa ecosystem, which appears to be self-sufficient in terms of its nutrient requirement (Leite and Valle, 1990). The objective of the present work was to study the throughfall and stem flow and to quantify nutrient recycling to the soil through these components of rainfall partitioning in a representative ABCS involving arecanut, cocoa, clove, pepper, coffee and banana.

The study was conducted at Central Plantation Crops Research Institute, Regional Station, Vittal, Karnataka, India(12° 15′N latitude and 75° 25′E longitude, 91 m above MSL). The climate is humid tropical with relative humidity of 96 % and average annual rainfall of 3670 mm distributed over 120 days. Mean temperature ranges from 19º C (minimum) to 36º C (maximum). The soil of the experimental site is sandy clay loam (laterite) with a pH of 5.25, 1.3 % organic carbon, 42 ppm N, 15.0 ppm P and 56.8 ppm K. The experiment was conducted in an existing arecanut garden established during 1965. The arecanut was planted at a spacing of 2.7 m x 2.7 m. Cocoa and clove were planted during 1983 at a spacing of 5.4 m in two separate rows. Coffee was planted during 1999 at 1.2 m spacing in every third row of arecanut. Banana was also planted during 1999 at 5.4 m intra-row spacing in cocoa and clove rows alternatively.

In an open area adjacent to the experimental site, a dark glass bottle of 2.5L capacity was placed on the ground to collect rain water. Inside the experimental plot, throughfall and stem flow were measured separately for arecanut, cocoa and clove in ABCS during 2001 (7^{th} August to 17^{th} November) and 2002 (30^{th} May to 9^{th} September). Water samples were collected to determine the nutrient content. Rainfall data was collected from the meteorological station located at the Institute. The throughfall was measured by the procedure explained below. A plastic tray of 100 cm long, 11.5 cm wide placed at 30 cm height from the ground was connected to glass bottle of 2.5 L capacity with 6.5 cm diameter funnel inserted in the neck. Collection bottles were changed at frequent intervals. All bottles were emptied and replaced by clean ones frequently in periods of heavy rainfall. For measuring stem flow, plastic sheet was tied around the stem spirally to the base of the stem and connected to dark glass bottle with funnel buried in the ground. The pH and NPK content in water samples of throughfall, stem flow and open rainfall were analysed on the day of sampling using standard procedures.

The amount of rainfall intercepted by component crops in ABCS varied with component species in different years (Table 1). In arecanut, throughfall and stem flow contributed 49-52 % and 25-43 % of the total rainfall, respectively implying a rainfall interception of 8-23 %. The very high fraction of stem flow could be due to the crown morphology of arecanut, which has inclined and concave shaped leaves. Cocoa intercepted higher amount of incident rainfall with the interception loss of 15.1 – 16.6 %, the rest of the rain passed through the dense and spreading canopy as throughfall (69.9 % in 2001 and 66.7 % in 2002) and stem flow (13.5 % in 2001 and 18.2 % in 2002). Clove intercepted 14.7-16.0 % of incident rainfall with throughfall amounting to 66.9-72.5 % as a result of thin and spreading crown. These ranges agree well with those reported in other studies (Duijsings *et al*., 1986; Silva and Okumara, 1996). Stem flow accounted for 12.8 - 43.0 % and 17-25 % of incident rainfall in 2001 and 2002, respectively in arecanut based cropping system. In case of arecanut, stem flow was higher than in cocoa and clove. This huge variation in stem flow can be attributed to differences in branch architecture, form and texture of leaves of component crops. This could lead to increased nutrient leaching when fertilizer is applied close to the stem of palms due to increased water input to the soil near the stem. The incident rainfall was more strongly correlated with throughfall and stem flow. The correlation coefficient (R) for throughfall with incident

Table 1. Throughfall, stem flow and interception loss in arecanut based cropping system

	Rainfall (mm) - 2001				
	August	**September**	**October**	**November**	**Total**
Rainfall	330.9	75.8	211.2	124.2	742.1
Arecanut					
Throughfall	173.9(52.5)	40.0 (53)	96.2(45)	56.9(45.8)	366.8(49)
Stem flow	139 (42)	30.3 (40)	95 (45)	54.6 (44)	319 (43)
Interception loss (%)	5.5	7.0	10.0	10.2	8.0
Cocoa					
Throughfall	228.3(69)	49.3(65)	154.2(73)	86.9(70)	518.7(69.9)
Stem flow	39.7(12)	10.6(14)	33.8(16)	16.1(13)	100.2(13.5)
Interception loss(%)	19.0	20.9	11.0	17.0	16.6
Clove					
Throughfall	251.5(76)	45.5(60)	147.8(70)	93.2(75)	538.0(72.5)
Stem flow	39.7(12)	8.34(11)	27.5(13)	19.9(16)	95.4(12.8)
Interception loss(%)	12.0	29.0	17.0	9.0	14.7
	Rainfall (mm)- 2002				
	May	June	July	August	Total
Rainfall	60.4	722.5	487.9	573.0	1843.8
Arecanut					
Throughfall	39.8(66)	461.3(64)	190.0(39)	273.7(48)	964.8(52)
Stem flow	15.9(26)	230.2(31)	100.0(20.5)	118.6(21)	464.7(25)
Interception loss (%)	8.0	5.0	40.5	31.0	23.0
Cocoa					
Throughfall	40.3(66.7)	471.6(65)	333.6(68)	383.7(67)	1229.2(66.7)
Stem flow	10.5(17.4)	142.6(19.7)	79.6(16.3)	102.6(17.8)	335.6(18.2)
Interception loss(%)	15.9	15.3	15.7	15.2	15.0
Clove					
Throughfall	49.5(82)	477(66)	328.5(67.3)	378.3(66)	1233.3(66.9)
Stem flow	7.7(12.7)	114.2(15.8)	82.7(16.9)	108.6(18.9)	313.2(17.0)
Interception loss(%)	5.3	18.2	15.8	15.0	16.1

Note: Figures in parenthesis indicate percentage of rainfall

rainfall varied between 0.991 - 0.999 for all component crops, while R value for stem flow varied between 0.945 for arecanut to 0.992 for cocoa and clove.

The pH of water sample from open rainfall (5.65) was more acidic than throughfall water leachate from arecanut (5.96), clove (6.13) and cocoa (6.21). Concentrations of N, P and K (Table 2) showed a clear pattern of enrichment in both throughfall and stem flow compared to rainfall. Boyer (1973) and Leite and Valle (1990) found that the throughfall represented an important source of nutrition in cocoa ecosystem. The concentration of N in throughfall and stem flow did not vary much due to component crop. The presence of P was found to be in trace amount only in water samples of all the precipitation components viz., throughfall, stem flow and open rainfall. Compared to nitrogen and phosphorus, potassium was leached in greater amounts. Henderson *et al.* (1977) also reported higher leachability of K in throughfall and stem flow in forest vegetation. Among the component crops, potassium was most leached from cocoa. This might be due to susceptibility of K ions to extensive cation exchange on leaf surface (Leite and Valle, 1990). Stem flow had more concentration of nutrients than throughfall and open rainfall. This can be attributed to repeated washing and leaching of nutrients from aerial parts of trees and also due to longer retention of stem flow than throughfall water on aerial surface.

Table 2. Nutrient concentrations (ppm) in throughfall and stem flow from different component crops and rain water in ABCS.

	2001				2002			
	pH	N	P	K	pH	N	P	K
Arecanut								
Throughfall	5.96	0.55	0.22	1.69	5.93	0.30	0.19	1.52
Stem flow		0.48	0.10	7.32		0.40	0.20	4.77
Cocoa								
Throughfall	6.21	0.40	0.66	8.11	6.19	0.90	0.46	7.61
Stem flow		0.57	0.89	20.82		0.90	0.58	9.03
Clove								
Throughfall	6.13	0.58	0.36	4.05	6.13	0.60	0.25	4.0
Stem flow		0.74	0.05	5.20		0.70	0.16	2.91
Rain water	5.65	0.38	NA	0.27	5.67	0.43	NA	0.32

The results indicated that arecanut intercepts less rainfall than cocoa and clove. Throughfall and stem flow added considerable quantity of N, P and K to soil. The addition of nutrients was more in cocoa and among nutrients K leaching through stem flow and throughfall was higher. Significant correlation existed among rainfall partitioning components in all the crops.

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