LITTERFALL AND NUTRIENT RETURNS IN ISOLATED STANDS OF *Persea gratissima* (AVOCADO PEAR) IN THE RAINFOREST ZONE OF SOUTHERN NIGERIA

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Abstract

This study assesses litterfall and nutrient returns to the soil in isolated stands of Persea gratissima in the rainforest zone of southern Nigeria. The study examined litter production, the concentrations of nutrients in litterfall, the returns of nutrient elements to the soil via litterfall, the relationship between litter production nutrient returns via litterfall, and determined the seasonal variations in litter production and the returns of nutrient elements via litterfall respectively. Data collection was on litterfall which was collected from February 2010 - January 2011. Data collected were statistically analyzed using the SPSS 15.0 version. Average litter production was 60.23 g/m²/yr and 77.31 g/m²/yr for the Persea gratissima and adjoining rainforest. Results of the Independent Samples T-Test revealed that there are significant differences between Persea gratissima and adjoining rainforest in litter production and returns of nutrient elements via litterfall. Except for Nitrogen, the concentrations of nutrient elements were similar. Results of Pearson's bivariate analyses showed that significant positive relationships exist between litter production and nutrients returned to the soil through litterfall at the 5% levels. However, litter production and the returns of nutrient elements vary with the seasons of the year, but the trend in the seasonal patterns of nutrient returns from Persea gratissima and adjoining rainforest is similar for K, Ca, Na and Mg. Persea gratissima return nutrients to the soil through litterfall, therefore its production should be encouraged to help in improving the soil nutrient status in rainforest areas.

Keywords: *Isolated tree stands, litterfall, nutrient returns, Persea gratissima, Southern Nigeria, Tropical rainforest.*

Introduction

Plants and soils in the rainforest ecosystems are closely related, and they influence one another (Nye and Greenland, 1960; Ekanade, 2007). Plants get their nutrients and moisture from the soil in which they grow. As the plants develop, they shed their leaves and branches as litter which decays to enhance the nutrients of the soil that are again used up by plants, a process known as nutrient cycling (Nye and Greenland, 1960; Wood *et al.,* 2006). Nutrients returned to the soil through litterfall help to maintain soil fertility by increasing the quantities of the nutrient elements in the soil (Bernhard-Reversat, 1993; Perez *et al.,* 2003). Therefore, there is a link between the soil and plant cover regarding cycling of nutrient elements.

Studies by Bernherd-Raversat, 1987; Vitousek and Sanford, 1986 have indicated that under tropical rainforests, plants and soils are in equilibrium involving an almost closed cycling of nutrients which is achieved by a very high rate of litter production, rapid mineralization and a rapid attainment of equilibrium with respect to organic matter relationships. However, whenever the forest is cleared for cultivation, this plant – soil relationship is disrupted irrespective of whether field or tree crops are planted. Even after tree crops in plantations have matured, with their characteristics closed canopy, environmental degradation is not arrested, at least when compared with a mature tropical rainforest (Adejuwon and Ekanade, 1988). Therefore the replacement of tropical rainforests with plantations of exotic tree species does not maintain the equilibrium which the native rainforest does. In this regards, it becomes imperative to study nutrient cycling under different tree species in order to account for the contribution of nutrient elements by tree stands to the soils underneath.

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In the rainforest zone of southern Nigeria, exotic tree plant such as Avocado pear (*Persea gratissima*) is planted to produce fruits and shade for resting places within the settlements and surrounding environment. These tree stands are found in isolation, with their canopies separated from other tree canopies because they are not cultivated in plantations. Although the economic importance of this tree plant is known, no effort has been previously directed to the consideration of its ecological implications in terms of nutrient cycling, after the natural plant covers have been cleared in the wetter rainforest ecosystem of southern Nigeria.

In the Nigerian rainforest ecosystems, studies on nutrient cycling with respect to litterfall as conducted by Muoghalu *et al.* (1993), and Muoghalu *et al.* (1994) were on a drier natural rainforest ecosystem; whereas the studies by Nwoboshi (1985), Oladoye *et al.* (2007), and Adedeji (2008) were conducted on plantation ecosystems. From these studies however, the contributions of individual tree stands to the soil in nutrient cycling were not effectively ascertained due to close canopy influence. Therefore, the results of such studies cannot provide a rational basis to account for understanding nutrient cycling under isolated tree stands.

This study becomes necessary, and it is perhaps, the first research on nutrient cycling under isolated tree stands in the rainforest zone of southern Nigeria. However, the choice of *Persea gratissima* (Avocado pear) species was determined by the differences in its crown architecture, stem and branch morphology, leaf size and arrangement.

The main objective of this study was to examine litter production and determined the contributions of nutrient elements to the rainforest soil by the isolated exotics. This is because studies on nutrient cycling provide insights into factors limiting tree growth and forest productivity.

Methodology

Study Area

This study was conducted on the isolated stands of *Persea gratissima* (Avocado pear) in the moist tropical rainforest of Orogun in Southern Nigeria. This study area falls within the humid sub-equatorial climate of Af Koppen's classification, with annual rainfall above 2000mm, and average temperature of about 26ºC (Efe, 2006; Ndakara, 2006).

The rainforest vegetation has been affected owing to centuries of human activities, such that the originally contiguous ecosystem now feature as island habitats or sacred groves (Ndakara, 2006; 2009), and confined to sacred places where human induced degradation activities are restricted. The rainforest tree species that featured prominently in the study area include *Piptadeniastrum africanum, Ceiba pentandra, Albizia adianthifolia, Terminalia superba, Alstonia boonei, Milicia excelsa, Ricinodendron heudelotii, Musanga cecropioidea* and *Antiaris toxicaria*.

Research Design and Data Collection

The study area was divided into 5 units based on the existing 5 quarters of the clan (Umusu, Unukpo, Imodje, Emonu and Ogwa). The quarters were so used in this study to ensure that every part of the study area was covered. In each quarter, 3 stands of the isolated trees were selected, making a total of 15 tree stands sampled. The selection of the isolated tree stands was based on the condition that they were not subjected to sweeping and burning which expectedly could have impact on the soil properties underneath the trees in the process of nutrient cycling. Also, each tree was so selected such that their canopies were separated from other tree canopies, thereby eliminating relationships with it. In each quarter, a sample plot of 30m × 30m divided into 3 quadrats of 10m × 30m was chosen from the adjoining rainforest cover to serve as control for this study (that is, 15 sample sites were established in the adjoining rainforest). The adjoining rainforest covers are matured native forest confined to sacred places, and have been referred to as island habitat or sacred groves (Ndakara, 2006; 2009).

Data collections were on litter production and litter nutrient concentrations. The litter samples were collected from the isolated tree stands and the adjoining rainforest; using litter bags with collection areas measuring 0.5m². Four (4) litter bags were set under each of the isolated tree stands, and each established sample points in the adjoining rainforest. The bags were made from sack materials and perforated at the bottom to allow rain water to drip out easily. In each month, 30 litter samples were collected from February 2010 to January 2011 respectively. This makes a total of 360 litter samples collected. The litter samples were put into labeled sacks and taken to the laboratory for analysis on the weight of litter as well as the concentrations of nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), sodium (Na), magnesium (Mg) and pH.

Laboratory Analyses of Samples

The litter collected was sorted into leaf, fruits, flowers and small wood litters. Apart from leaf and flower litter, only litter of ≤ 2.5 cm in diameters was included in this study. The litter samples were dried to constant mass in an electric oven at temperature of 105ºC for 24 hours. Analyses were based on litter production and nutrient concentrations. The oven-dried litter samples were weighed by the use of "top loading electronic balance". The weights represented the litter production for the isolated tree stands and the adjoining rainforest, and reported in g/m². The oven-dried litter samples were then ground into powdery form and analyzed for the concentrations of elements such as nitrogen, phosphorus, potassium, calcium, sodium, magnesium and pH. To determine the concentrations of nitrogen and phosphorus, this study adopted the approach of a modified Kjeldahl digestion on a Tecator 2000 Digestion System (Wood *et al.,* 2006). The nutrient cations (K, Ca, Na and Mg) were analyzed by digesting the ground litter samples in HNO_3 / H_2O_2 on a block at 105ºC. The samples were then re-dissolved in 50ml of 10% nitric acid for analysis using Spectro CIROS CCDE Inductively Coupled Argon Emission Plasma Spectrometry (ICP). The pH values were determined by the use of pH meter.

Statistical Analyses of Data

Both descriptive and inferential statistics were employed using the SPSS 15.0 version. Graphs were used to show the seasonal variations in litter production and the returns of nutrient elements to the soil. The independent samples t-test was employed in the analyses of the differences in litter production, nutrient concentrations and the returns of nutrient elements between the isolated tree stands and the adjoining rainforest. While the Pearson's bivariate correlation analysis was employed in the assessment of the relationship between litter production and nutrient returns.

Results and Discussion

Litter Production

Litter production varied between the isolated stands of *P. gratissima* and the adjoining rainforest. The mean annual litter production for the stands of *P. gratissima* and adjoining rainforest are 60.23 and 77.31 g/m² respectively (table 1). The much lower litter production observed in the stands of *P. gratissima* could be attributed to the tree crown architecture, while the close canopy influence in the adjoining rainforest may have enhanced the amount of litter produced under the forest cover. However, the observed difference in litter production between the isolated tree stands and the adjoining rainforest was significant at the 5% confidence level when tested with the Independent samples t-test statistics (table 2).

The amount of litter produced by the isolated trees and the adjoining rainforest also varied seasonally, and obviously with the phonological changes which occurred in the different tree species in the adjoining rainforest. While litter production was higher in Avocado pear between August and January, it was higher in the adjoining rainforest between November and March (fig. 1). The pattern of seasonal variation in the production of litter in the adjoining rainforest is similar to the observed patterns in studies by Muoghalu et al (1993) in a Nigerian rainforest; and Hermansah et al (2002) in the tropical rainforest of Western Sumatra, Indonesia, where litter production was also highest in the dry season months; but differ from the study by Pragasan and Parthasarathy (2005) in the tropical dry evergreen forests of south Indian. However, it could be deduced that the seasonal trends in litter production between Avocado pear stands and the adjoining rainforest are similar. Although litter production in the adjoining rainforest is higher than that of the Avocado pear stands, the pattern of litter production is quite similar through the seasons of the year.

Nutrient Concentrations and Returns to the Soil

The concentrations and returns of nutrient elements in litterfall vary between the isolated tree stands and the adjoining rainforest. Table 3 shows the mean annual concentrations of nutrient elements in litterfall. Nutrient elements were higher in the adjoining rainforest than in the isolated tree stands.

Similarly, the returns of nutrient elements to the soil were higher in the adjoining rainforest than in the isolated tree stands (table 4). Generally, the concentrations and returns of Ca, N and K were higher than those of Mg, P and Na respectively.

The results of the concentration of nutrient elements in the adjoining rainforest which are higher with Ca, N and K than those of Mg, P and Na, corroborate with findings in the studies by Nye and Greenland (1960) where the concentrations of N, P, K, Ca and Mg are 19, 0.7, 6.5, 19.6 and 4.3 respectively. While the results of the returns of nutrient elements in the adjoining rainforest which was higher with Ca, N and K than those of Mg, P and Na, corroborate with findings in the study by Muoghalu et al (1993) where the returns of N, P, K, Ca and Mg are 6.6, 4.0, 4.5, 9.7 and 1.5 respectively.
The mean differences in the concentrations and returns of nutrient elements in litterfall between *P. gratissima* and the adjoining rainforest were tested with the independent samples t-test. The results for the concentrations of nutrient elements in litterfall (table5) shows that apart from the concentration of nitrogen which is significant at 1% levels, the concentrations of other nutrient elements (P, K, Ca, Na and Mg) are not significantly different at the 5% levels. However, the t-test results for the returns of nutrient elements to the soil via litterfall (table 6) shows that there are significant differences in the returns of N, P, K, Ca, Na and Mg to the soil between the isolated stands of *P. gratissima* and the adjoining rainforest at the 5% levels of confidence. This variation could probably be due to the differences in the tree species composition in the adjoining rainforest because, studies by Proctor (1983), Muoghalu *et al* (1993), Hermansah *et al* (2002), Pragasan and Parthasarathy (2005) have revealed that the cycling of nutrient elements vary with variations in tree species composition.

The concentrations and returns of all the nutrient elements were higher in the adjoining rainforest than those in the isolated stands of *P. gratissima*. The higher flux in these nutrient elements could presumably be due to their high availability in the soil. The order of nutrient concentrations and returns to the soil through litterfall as observed in the isolated tree stands is Ca > N > K > Mg > P > Na while that of the adjoining rainforest is N > Ca > K > Mg > P > Na. The observed order for the isolated tree stands is in line with that observed by Mueller-Dombois *et al* (1984), and Muoghalu *et al* (1993); while that of the adjoining rainforest corroborates findings by Bernhard-Reversat (1993), and Perez *et al* (2003).

pH Values in Litter

The monthly pH value of litter varies between the isolated stands of *P. gratissima* and the adjoining rainforest. The mean annual pH values for the stands of *P. gratissima* and adjoining rainforest are 5.08 and 5.18 respectively. This indicates that pH value in the adjoining rainforest is higher than that of the isolated stands of *P. gratissima*. However, the observed levels of pH concentration shows that acid content in litter from the stands of *P. gratissima* and the adjoining rainforest are both moderately concentrated.

Seasonal variations in nutrients returned to the soil

The trend in the returns of nutrient elements to the soil through litterfall between the isolated tree stands and the adjoining rainforest varies with the seasons of the year (fig 2 – 7). From fig 2, the stands of *P. gratissima* returned the highest nitrogen in the month of May, while the adjoining rainforest returned the highest nitrogen in the month of March.

The seasonal pattern of nitrogen returns shows that *P. gratissima* returned more nitrogen to the soil during the rainy months, while the adjoining rainforest trees returned more nitrogen in the month of March, which is the beginning of rainy season in this study area. From fig 3, the stands of *P. gratissima* returned the highest phosphorus in January, while adjoining rainforest returned the highest phosphorus in the month of March respectively. This shows a marked variation in the returns of phosphorus through litterfall between the isolated stands of *P. gratissima* and the adjoining rainforest. The seasonal pattern of phosphorus return shows that while the adjoining rainforest returns more phosphorus to the soil in the early rains, *P. gratissima* stands returned more phosphorus to the soil during the dry season respectively. The returns and trend in the seasonal patterns of nutrient returns to the soil is quite similar for K, Ca, Na and Mg respectively between the *P gratissima* stands and the adjoining rainforest. The highest returns of these nutrient elements were observed in the month of January in the stands of *P gratissima*, while in the adjoining rainforest they were observed in the month of February (fig 4 -7).

The seasonal pattern therefore shows that both the isolated stands of *P. gratissima* and the adjoining rainforest return more nutrient elements to the soil during the dry season months. However, the seasonal pattern of nutrients return in the adjoining rainforest is similar to that observed by Muoghalu *et al* (1993). This confirms that, in the process of nutrient cycling, the returns of nutrient elements vary with the seasons of the year.

Interrelationships between Litter Production and Nutrient Returns

The results of Pearson's bivariate correlation analysis as presented in table 7, shows that the relationships between litter production and the nutrient elements returned to the soil through litterfall are all significant and positively correlated for the isolated stands of *p. gratissima* and the adjoining rainforest.

Conclusions

Findings in this study revealed that litter production varied between the stands of *P. gratissima* and the adjoining rainforest, while similarity was observed in the trends in seasonal variations in the returns of nutrient elements. Acid content of litter from the stands of *P. gratissima* and the adjoining rainforest are both moderately concentrated. While litterfall was observed as an important source of nutrients return to the soil in the process of nutrient cycling, a positive relationship was observed between litter production and the returns of nutrient elements. Therefore, litterfall by the isolated stands of *P. gratissima* helps to improve the soil nutrient status characteristics underneath the tree stands in the process of nutrient cycling. Therefore, suggests growing of *P. gratissima* should be encouraged in the deforested rainforest so as to maintain the soils of the ecosystem.

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Table 1 Monthly litter production in g/m²

Months	Avocado pear (*Persea gratissima*)	Adjoining Rainforest
Feb	50.62	128.40
Mar	45.40	148.62
Apr	41.49	62.95
May	34.12	50.16
Jun	40.02	48.71
Jul	41.03	40.47
Aug	63.26	49.20
Sep	68.62	50.28
Oct	69.86	54.61
Nov	80.38	82.11
Dec	94.96	104.92
Jan	92.94	107.24
Mean	**60.23**	**77.31**

Source: Field work

Table 2 Independent Samples T-Test for Litter production between *Persea gratissima* and Adjoining Rainforest

Sample	**Sample site**	**N**	**Mean**	**M.D**	**S.D**	**S.E.D**	**D/F**	**F**	**T**	**Sig.**
Litter production	*P.gratissima*	12	60.23	17.08	21.27	12.16	22	5.064	1.405	.035
	Rainforest	12	77.31		36.35					

Table 3 Mean concentrations of nutrient elements in litterfall in mg/g

Nutrient elements	Sites	
	Avocado pear *(Persea gratissima)*	Adjoining rainforest
Nitrogen	4.51	10.69
Phosphorus	0.70	0.72
Potassium	3.43	3.69
Calcium	9.00	9.53
Sodium	0.51	0.53
Magnesium	3.13	3.18

Source: Field work

Table 4 Mean annual returns of nutrient elements via litterfall in kg/ha

Nutrient elements	Sites	
	Avocado pear *(Persea gratissima)*	Adjoining rainforest
Nitrogen	2.42	9.08
Phosphorus	0.42	0.60
Potassium	2.14	3.39
Calcium	5.37	7.81
Sodium	0.31	0.49
Magnesium	1.87	2.57

Source: Field work

Table 5 Summary of the Results Obtained by Independent Samples T-Test for Nutrient Concentrations in Litterfall between *Persea gratissima* and Adjoining Rainforest

Nutrient elements	**Sample site**	**N**	**Mean**	**M.D**	**S.D**	**S.E.D**	**D/F**	**F**	**T**	**Sig.**
Nitrogen	*P. gratissima*	12	4.51	6.18	1.74	0.88	22	1.379	6.992	.000
	Rainforest	12	10.69		2.52					
Phosphorus	*P. gratissima*	12	0.70	.02	.14	0.06	22	.072	.304	.792
	Rainforest	12	0.72		.15					
Potassium	*P. gratissima*	12	3.43	.25	1.67	.710	22	.223	.356	.642
	Rainforest	12	3.69		1.81					
Calcium	*P. gratissima*	12	9.00	.53	1.00	.577	22	3.216	.915	0.087
	Rainforest	12	9.53		1.73					
Sodium	*P. gratissima*	12	0.51	.02	0.15	.063	22	.360	.319	.555
	Rainforest	12	0.53		0.16					
Magnesium	*P. gratissima*	12	3.13		0.40		22	.056	.298	.815
	Rainforest	12	3.18		0.42					

Table 6 Summary of the Results Obtained by Independent Samples T-Test for Nutrient returns to the soil via Litterfall in *Persea gratissima* and Adjoining Rainforest

Nutrient elements	Sample site	N	Mean	M.D	S.D	S.E.D	D/F	F	T	Sig.
Nitrogen	*P. gratissima*	12	2.42	6.66	0.48	1.744	22	17.837	3.820	.000
	Rainforest	12	9.08		6.02					
Phosphorus	*P. gratissima*	12	0.42	0.18	1.78	.125	22	10.512	1.415	.004
	Rainforest	12	0.60		0.39					
Potassium	*P. gratissima*	12	2.14	1.25	1.52	.910	22	7.245	1.373	.013
	Rainforest	12	3.39		2.76					
Calcium	*P. gratissima*	12	5.37	2.44	1.95	1.483	22	15.579	1.644	.001
	Rainforest	12	7.81		4.76					
Sodium	*P. gratissima*	12	0.31	0.174	0.16	.103	22	7.999	1.685	.010
	Rainforest	12	0.49		0.32					
Magnesium	*P. gratissima*	12	1.87	0.696	0.70	.464	22	13.133	1.501	.002
	Rainforest	12	2.57		1.45					

Table 7: Pearson's Bivariate Correlations between Litter Production and Nutrient Returns

Sites	Litter production	Nutrient elements: Nitrogen	Phosphorus	Potassium	Calcium	Sodium	Magnesium
P.gratissima	Litter	.782*	.848**	.760**	.911**	.854**	.906**
	Sig. (2-tailed)	.024	.000	.004	.000	.000	.000
	N	12	12	12	12	12	12
Rainforest	Litter	.972**	.991**	.944**	.972**	.949**	.987**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000
	N	12	12	12	12	12	12

** Correlation is significant at the 0.01 level (2-tailed)
* Correlation is significant at the 0.05 level (2-tailed)

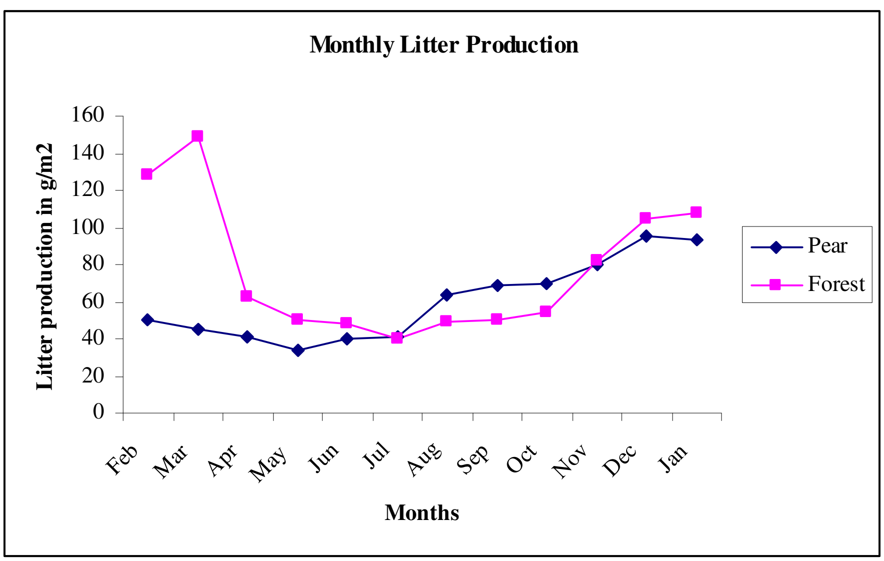

Fig.1: Seasonal Variations in Litter Production

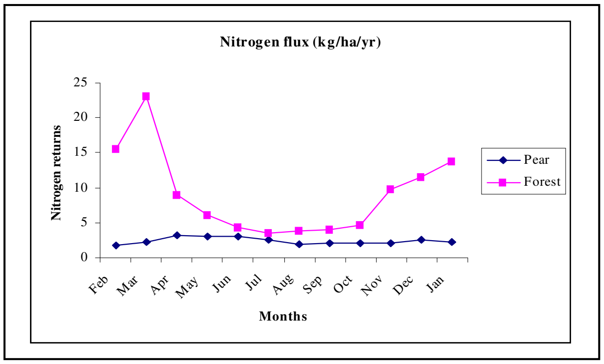

Fig 2: Seasonal Variations in Nitrogen Flux

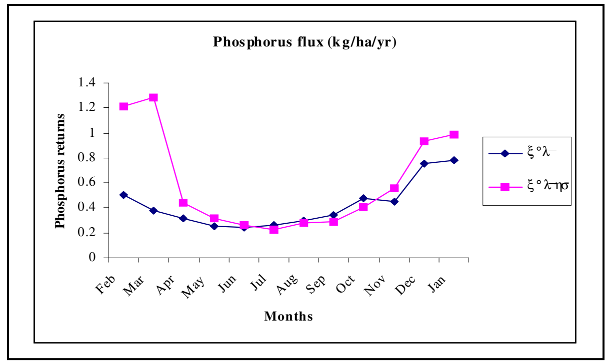

Fig 3: Seasonal Variations in Phosphorus Flux

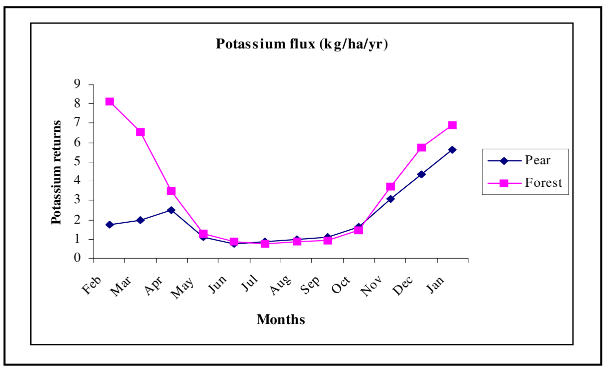

Fig 4: Seasonal Variations in Potassium Flux

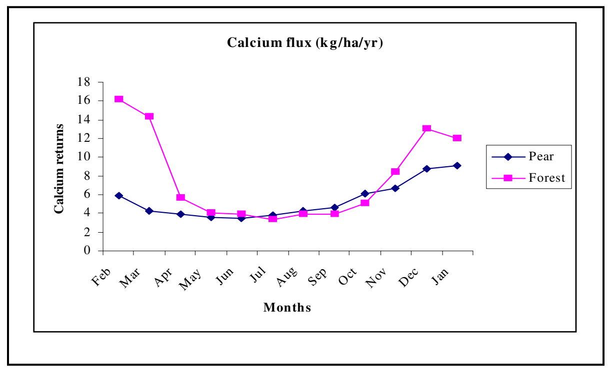

Fig 5: Seasonal Variations in Calcium Flux

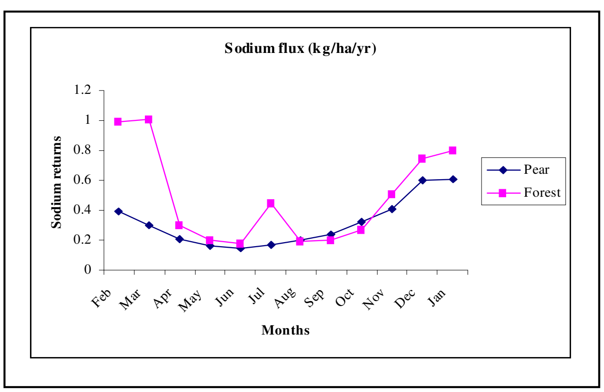

Fig 6: Seasonal Variations in Sodium Flux

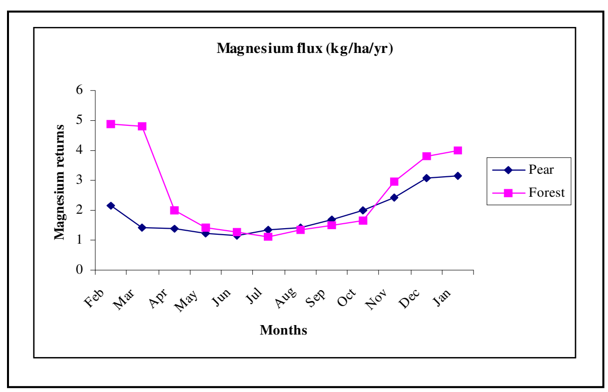

Fig 7: Seasonal Variations in Magnesium Flux