VOL. 5, NO. 2, MARCH 2010 ISSN 1990-6145
ARPN Journal of Agricultural and Biological Science

www.arpnjournals.com

LITTERFALL DYNAMICS IN *Leuceana leucocephala* (Lam) de wit PLANTATION IN THE NIGERIAN DERIVED SAVANNA

Oladoye A. O.[1], Ola-Adams B.A.[2] and Adedire M. O.[1]
[1]Department of Forestry and Wildlife Management, University of Agriculture, Abeokuta, Nigeria
[2]Crescent University, Abeokuta, Ogun State, Nigeria
E-Mail: segun11us@yahoo.com

ABSTRACT

The pattern of litterfall and impact of rainfall and temperature variables on litterfall were investigated in *Leuceana leucocephala* plantation in the University of Agriculture, Abeokuta, Ogun State, Nigeria. Litterfall pattern was examined for 12 months using twenty wooden litter trays with nylon net (1m x 1m x 0.2mm) distributed randomly within the study site. The litter trays were raised above ground level with pegs of 20cm high to avoid contact with soil. Total annual litterfall was 12,435.75 kg/ha/yr., leaf, twig, pod, seed, and flower components accounted for 65%, 27.5%, 4%, 3.76% and 0.32%, respectively. The quantity of litterfall was higher between September and November. This indicates the transition phase between the wet and dry season. However, litterfall was more during the wet season and accounted for 54.33% of the total litter fall during the year. This reflects the greater number of days considered for this season. Only 45.67% of the total litter fell during the dry season. The coefficients (R) of multiple regression analysis showed that number of wet days contributed significantly to the monthly total litter and leaf litter (72.9 and 73.4) respectively. Litterfall was negatively correlated with monthly temperature. The general trend of litter components was in the order leaf > wood > seed > pod > flowers. Leaf litter was high in dry season, high wood fall was observed in September and this reflects the heavy rains and storms that consistently occurred during the wet season. High value of seed collected in September reflects the impacts of rainfall and wind that led to the fall of premature seeds.

Keyword: litterfall, pattern, leaf litter, wet days, *Leuceana leucocephala* plantation.

INTRODUCTION

Energy flow and nutrient cycling are essential for the functioning of an ecosystem. Litterfall is a fundamental process in nutrient cycling and it is the main means of transfer of organic matter and mineral elements from vegetation to the soil surface (Vitousek and Sanford, 1986; Regina *et al*., 1999). The analysis of litter quality and quantity and its rate of decomposition are highly important for the understanding of energy flow, primary productivity and nutrient cycling in forest ecosystems. Litterfall is a major source of organic matter in forest ecosystem into soil subsystem (Herbohn and Congdon, 1998; Scarascia *et al*., 2000; Temel, 2003). Litterfall has also been described as a major pathway for the return of organic matter and nutrients from aerial parts of the plant community to the soil surface (Proctor, 1983; Vitousek, 1984; Hermansah *et al* 2002, Odiwe and Moughalu 2003). The advantages of litterfall in deciduous tree lies in the resulting reduced rate of transpiration while at the same time the return of leaf and other materials and their breakdown on the surface litter releases mineral nutrients to the soil which are available for recycling (Anderson and Swift, 1983; Vitousek, 1984, Ola-Adams, 1987).

This study therefore deals with the amount and pattern of litterfall and relationship between litterfall and some environmental variables in *Leucaena leucocephala* plantation.

MATERIALS AND METHODS

Study site

The study area is *Leucaena leucocephala* plantation the site is on latitude 7^0 and 7^0 58^1N and on the longitude 3^0 2^1E and 20^0 37^1, 600m above sea level. The general topography of the site is undulating land terrain while local topography is upper mid-slope. Soil is under laid by the pre-cambian metamorphic rocks of the basement complex (Jones and Hockey, 1964) with bed rock consisting predominantly of granite gneisses, bounded biotite horn blende gneises, quartrite and quarz schists. The soil is a fertile sandy loam, very dark in colour at the top surface and greyish brown in the subsoil with occasional areas of loamy soil. The landscape is undulating. The area has a tropical climate with a bimodal distribution of rainfall. It lies within the humid lowland region (Keay, 1953) with two distinct seasons. The wet season extend from April to October while the dry season extends from November to March. The mean annual rainfall is 1113.1mm. The bimodal distribution of rainfall has its peaks in July and September and break in August. Generally, the rainfall could be heavy and erosive and sometimes accompanied by lightening and thunderstorms at the beginning and the end of the rainy season. The mean monthly temperature varies from 22.74^0C in August to 36.32^0C in March. The relative humidity is high ranging from 75.52% in February to 88.15% in July (Aiboni, 2001).

Climatic data for the study year, July 2004 to August 2005, were collected from University of Agric.

Meteorological Station Abeokuta. These include the rainfall variable and temperature variables (Table-1).

Table-1. Rainfall and temperature variables (July 2004-August 2005).

Month	No. of rain days	No. of wet days	Mean monthly rainfall (mm)	Minimum Temp (^oC)	Maximum Temp (^oC)
July 04	5	4	12.54	22.30	30.26
Aug 04	8	5	7.59	22	29
Sept 04	9	9	14.48	22	36
Oct 04	5	5	7.48	22	31
Nov 04	-	-	-	23	31
Dec 04	-	-	-	23	31
Jan 05	-	-	-	21.17	31
Feb 05	4	3	14.17	24	35
Mar 05	2	1	11.30	22	34
Apr 05	5	5	52.05	23	35
May 05	9	7	16.96	24	31
Jun 05	7	8	32.44	26	31
July 05	10	8	4.08	23	29
Aug 05	3	2	2.28	23	28

Litterfall sampling

Twenty wooden litter trays (1m x 1m x 0.2mm) with nylon net were distributed randomly within the plantation. The trays were slightly raised above the ground with pegs of about 20cm high this was done to avoid contact with the soil, so as to prevent leaching of the nutrient as a result of contact with soil.

The litter was collected from each tray once in a month for a period of 12 months (July 2004 - June 2005), except during the rainy season when it was done twice in a month to avoid excessive leaching of nutrient from the litter.

The collected materials were weighed, separated into components of leaves, twigs, flowers, seeds and pods and oven-dried at 100^{o}C to a constant weight and ground prior to chemical analysis.

Statistical analysis

Data collected were subjected to multiple regression analysis using total litter and leaf litter components as dependent variables with different combination of rainfall variables i.e. No. of wet days, No. of rain days and mean monthly rainfall and temperature variables i.e. minimum and maximum temperature as independent variables.

Step wise regression was further adopted to check the level of relationship that exists between each of the independent variables and the dependent variables.

$Y = a + b_1x_1 + b_2x_2 + b_3x_3$

Y = the dependent variables

a = intercept of dependent and independent variables

b = slope or sample regression co-efficient

x = the independent variable.

Correlation analysis was carried out to examine if relationship exist between litter component and climate i.e. maximum temperature, mean monthly rainfall and leaf litter component. Correlation analysis was also carried out on litter decomposition data

$$\text{Litterfall (kg/ha/yr)} = \frac{\text{Total litter (y) x 1000 (y/kg)}}{\text{Area of litter tray x 10,000 (m}^2\text{/ha)}}$$

RESULTS

Total litterfall for the study site was estimated at 12435.575 kg/ha/yr and the mean monthly litter was 103.63 kg/ha/month (Table-2). In addition, the annual litter components were 801.453 kg/ha/yr for leaf litter, 341.36 kg/ha/yr for twig, 46.831 kg/ha/yr seed, 3.544 kg/ha/yr for flower and 49.711 kg/ha/yr pod component.

Leaf litter component accounted for 65% of the total litter, followed by twig (27.5%), pod (4%), seed (3.76%) and flower (0.32%) as shown in Table-2. The leaf litter production was responsible for a high percentage of total litter production. Litter fell continuously throughout the year with highest collection in September and November.1724.36g/m^2 for September and 1664.74g/m^2 for November and these accounts for 13.86% and 13.38% respectively of the total litter. The lowest value recorded was in March (483.97). The peak of leaf litter was in November, twig was in September, for seed and pod in

February, and flower was at its peak in January. The highest amount of leaf, flower and fruit litter was recorded during the dry months i.e. November and March. The highest twig litter falls occurred at the beginning and end of the rainy season i.e. in April and September (Table-2).

The average daily litterfall for the month with the highest peak was 57.40 g/m/day. The peak of seed component was in February and followed by January collection. These collectively account for 50% of the total seed production for the period of data collection; however no seed was collected in July. Similar peak was recorded for pod and these collectively accounted for 38%. No flower was collected for May and June, July collection.

The seasonal pattern of total litter and litter components are shown in Figures 1 and 2, respectively. Litterfall continuously throughout the period of investigation in *Leucaena leucocephala* though varied seasonally. The pattern of total litterfall is bimodal with high litterfall in September and November and low litterfall in March The result of this study follows a general trend of litter component in this order leaf > wood > seed > pod > flower.

Table-2. Quantities of litterfall in a year in g/m^2 in *Leucaena leucocephala* plantation (Figures in parenthesis are percentage of total).

Month	**Total litter** (oven dry)/g	**Leaf litter** (g)	**Twig** (g)	**Seed** (g)	**Flower** (g)	**Pod** (g)
July 04	637.06 (5.16)	513.65	115.44	-	-	8.00
Aug 04	743.32 (5.98)	524.17	198.86	7.66	1.33	11.30
Sept 04	1724.36 (13.86)	1038.97	524.88	83.25	4.10	73.16
Oct 04	1281.59 (10.30)	909.37	301.43	36.88	2.60	31.31
Nov 04	1664.74 (13.38)	1271.41	339.56	19.04	5.66	29.07
Dec 04	1588.07 (12.76)	1172.73	381.56	7.16	6.60	20.53
Jan 05	1289.05 (10.36)	764.03	344.95	81.52	7.62	90.94
Feb 05	655.36 (5.27)	195.36	211.57	142.52	5.00	100.88
Mar 05	483.97 (3.89)	194.36	213.22	34.80	1.50	40.09
Apr 05	613.43 (4.93)	299.20	241.65	39.99	1.03	31.56
May 05	813.99 (6.54)	512.22	264.43	10.92	-	26.42
Jun 05	939.78 (7.55)	619.03	282.33	4.57	-	33.85
Total kg/ha/mn mean	12435.75 1243.575 103:6369	8014.53	3419.36	468.31	35.44	497.11
% Total		64.42	27.50	3.76	.32	4

Fig.1: PATTERN OF TOTAL LITTERFALL IN *Leueana leucocephala* PLANTATION

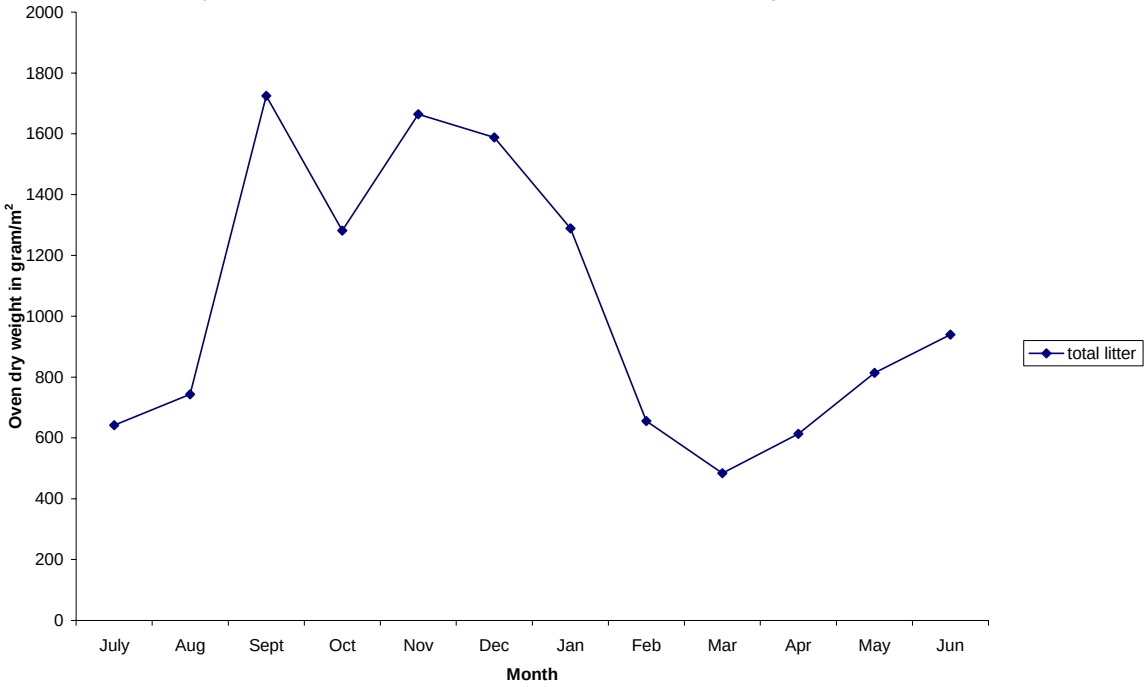
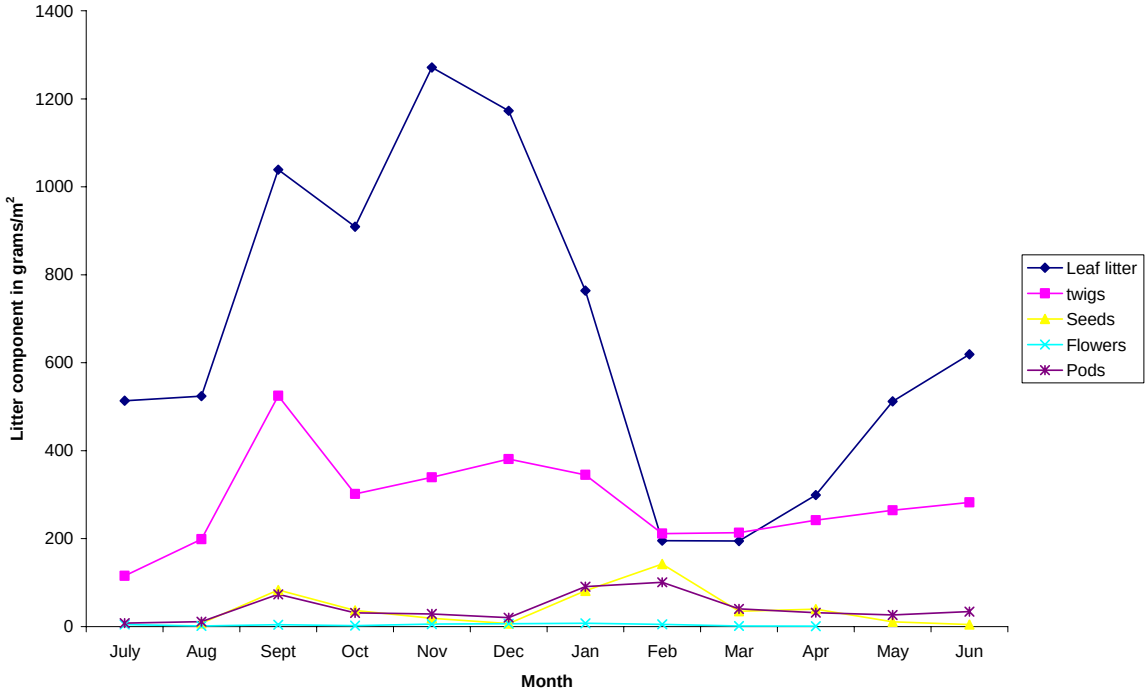


FIG.2: PATTERN OF LITTER COMPONENTS IN *Leuceana leucocephala* PLANTATION



Litterfall and climatic variables

Regression analysis shows that number of wet days is significant ($P<0.05$) (Table-3). Number of wet days accounted for 72.9% and 73.4% of total litter and leaf litter respectively .Significantly positive correlation was observed between total litter and number of wet days, it was also significant for leaf litter and number of wet days as shown in Table-3.

Table-4 revealed that positive correlation was observed between no. of rain days and total litter on one hand and leaf litter on the other hand however negative relationship was observed for mean monthly rainfall and total litter and leaf litter separately, similar observation was recorded for minimum temperature and maximum temperature against total litter and leaf litter. Of all the three rainfall variables, either individually or in groups, it was number of wet days

that adequately describe a high level of relationship with total litter and leaf litter.

Table-3. Stepwise regression coefficient of independent variables used in predicting total litter and leaf litter in *Leucaena leucocephala*.

Dependent	Constant	No. of wet days	Coefficient of M.C. (R)	Level of sig
Total litter	276.757	115.043	0.729	0.0268*
Leaf litter	82.222	86.518	0.734	0.024*

* $p<0.05$

Table-4. Correlations between rainfall and temperature variables and total litter and leaf litter in *Leucaena leucocephala*.

Climatic variables	Total litter	Leaves litter
No. of rain days	0.565	0.609
No. of wet days	0.729*	0.734*
Mean monthly rainfall	-0.199	-0.255
Min. temp.	-0.252	-0.255
Max. temp.	-0.485	-0.602*

* $p>0.05$

DISCUSSIONS

Total litterfall and the percentage contribution of the different litter components (leaf, wood, seed, pod and flowers) are shown in Table-2 with leaf litter accounting for about 65% of the entire litter production. Similar findings have been recorded by (Ola-Adams and Egunjobi 1992; Muoghalu *et al* 1993; Pausas, 1997; Harmansah *et al*., 2002; Odiwe and Muoghalu 2003; Yu sheng Yang *et al*., 2004).

The greatest litter production occurred between September and November which accounted for 13.86 and 13.38% total litter respectively. This may indicate the transition phase between the wet and dry season, similar to the studies of Reinaldo and Philip (1995). Litter production was greatest in this study during the wet season, due to the greater number of days considered for this season in the year, more so, the greatest daily production of total litter occurred in September ($57.40 g/m^2$) and this coincide with the period of highest number of wet days and number of rain days, However the lowest litter production in March probably due to lack of rainfall and deciduous habit of the *Leucaena*. A similar trend has been recorded for *Eucalyptus globulus* in Ethiopia (Lisanework *et al*., 1994). The greatest monthly productions of total litter that occurred in September may also be associated to the beginning of a phase of high temperature associated with torrential rains and strong wind.

Leaf litter was responsible for a high percentage of the total litter production, has also been found in other studies. In Amazonian forest (Reinaldo and Philip 1995), Ola-Adams and Egunjobi (1992), in *Terminalia superba* and Teak, Hermansah *et al*. (2002) in Rainforest in West Sumatra, Yusheng yang *et al*. (2004) in China. The production of leaf litter increased with total litter. High peak of wood litter during the rainy season may be associated with strong winds which usually occur during the dry season. Significant rise in woody component was recorded during the dry season between February and March, this may be connected to period when it appears there was little leaf on the trees and woody branches are dry and these are easily defeated by wind. This corresponds to the period of minimum leaf fall and total litter. Woody component accounted for 27.5% of the total litter production, which is slightly lower than the value recorded by Reinaldo and Philip (1995); Hermansah *et al*., (2002) though not the same species. However higher values were recorded by Ola-Adams (1978), Muoghalu *et al*., (1993); Odiwe and Muoghalu, (2003), and Yu Sheng yang *et al*., 2004 i.e. 14 %, 7-14%, (10-38) % and 15% respectively.

Quantity of seed recorded in this study appear to follow the normal trend i.e. the highest seed production was in January and February, this may indicate the period of seed production for *leucaena*, however a higher value recorded in September may not be unconnected to premature fall of seed probably due to high wind after rainfall. The result showed that seed collection can still be done till April for subsequent planting in Agro forestry. This same trend stands for pod component. No flower was produced in May, June and July.

The peak of litterfall varies with species, litterfall more in wet season in some species than in dry season. Similar findings were recorded by Ola-Adams and Egunjobi (1992) for *Terminalia superba, Eucalyptus globulus* by Linanework and Michelsen (1994) and Pinus *sylvestris* by Pausas (1997). The peak of leaf fall in November in this study witnessed a similar trend in *Sterculia tragacantha* in Ibadan (Madge, 1965), *Brachystegia nigerica, Celtis zenkeri* (Ola-Adams, 1978). This may be due to the fact that deciduous trees shed their leaves throughout the year but more during the dry season. The total amount of litter when compared with other studies is lower than what was recorded by Nwoboshi (1981). This may be associated with the difference in site and species. Vitousek, 1984; Lonsdale 1987 reported that site differences have been observed to have effect on total and seasonal fall of litter. In this study, a greater seasonality of litterfall with relatively greater litterfall

between September and January, However a combination of environmental factors may be responsible for continuous flux of litter throughout the year.

Litter fall throughout the year with rate particularly high in wet season accounted for 54.33% of the total litter produced the result differs when compared with other studies of Ola-Adams and Egunjobi (1992); Scott *et al*., 1992; Reinaldo and Philip (1995). The peak of leaf fall in *Leucaena* was in November and December; this major peak is related to the dry period when there was no rainfall but high temperature.

The result of this study follow the general trend of litter component in this order leaf > wood > seed > pod > flowers. This is comparable with Lisanework and Michelsen (1994), Reinaldo and Philip (1995), Regina *et al*., 1999; Hermansah *et al*., (2002), Odiwe and Muoghalu (2003), Yu Sheng Yang *et al*., (2004); However, this trend was mainly determined by the quantity or percentage contribution of each component. The peak of litterfall recorded during the wet season for *Leucaena* is comparable with the studies of Corinforth (1970) for mora (*Mora excelsa* Beth); *Pinus caribaea* (Egunjobi and Fasheun 1972), *Alnus nepalensis* (Eklabya and Ambasht, 1988), Ola-Adams and Egunjobi (1992) for *Terminalia, Eucalyptus globulus and Cupressus lusitianica* (Lisanework and Michelson, 1994), natural forest (Hermansah *et al*., 2002),

Both the pattern of leaf litter and total litter appeared similar in the study. This might be due to the fact that leaf litter contributed over 60% of the total litter. The lowest value of leaf-litter recorded in February and March may be due to deciduous nature of tree species which implies that there was little leaves on the standing crop and this coincide with period when twig produced per month exceed monthly leaf production. The high wood fall in September reflects the heavy rains and storms that consistently occurred during the wet season causing both tree and large branch falls into the litter trap. However, twig component increased with total litter. A sudden rise in total litter and leaf litter was noticed in April, this may indicate the beginning of rainy season, thus it can be deduced that litter fall and leaf fall are highly associated with climate specifically rainfall

The reproductive structures i.e. seed, flowers showed an irregular cycle and seasonal variation was not evident. The same phenomenon was observed by Cuevas and Medina (1986), Reinaldo and Philip (1995) and is probably due to the differences in species found in different tropical environment and their different phenological rhythms (Fassbender and Grimm, 1981).

Litterfall pattern in *Leucaena* plantation as in any other forest ecosystem type is determined by a variety of factors such as successional stage in its development and also related to microclimatic differences (Facelli and Picket, 1991), such as amount and time of rainfall or degree of water stress (Ola-Adams and Egunjobi 1992), Variations in these factors could affect qualitatively and quantitatively the amount and composition of litter from year to year (Lonsdale, 1987). Patterns of litter and leaf fall may be affected by differences in altitude, climate, aspect and latitude, wind storms, seasonal drought, and by the shortening of day-length during autumn from one area to another rather than stand and species differences. (Tanner 1980, Proctor *et al*., 1989, Williams and Tolome, 1996, Enright, 1999, Cecilia *et al*., 2003). Therefore it was reasonable to expect a seasonal or spatial variation of the litterfall pattern in the present study. The high variability of litter production as a major source of organic pool in the forest ecosystem may affect soil variability through nutrient fluxes.

The analysis showed that both total and leaf litterfall are not significant when compared with mean monthly rainfall, number of wet days, number of rain days and minimum and maximum temperature. However, when compared individually with the different independent variables, only the number of wet days is significant ($P > 0.05$) i.e. contributed greatly to the total litter and leaf litter.

Significant positive correlation observed between leaf litter and numbe of wet days with the highest value in dry months may be partly due to water stress during the dry season, as reported by Muoghalu *et al*., (1993), deciduous habit of *Leucaena.* Ola-Adams and Egunjobi, (1992) also reported similar observation for *Tectonia grandis,*, (Hermansah *et al*., (2002) for natural Forest in West Sumatra. A negative significant correlation recorded for total litter and leaf litter with temperature may be explained by the assumption of Jackson (1978); Muoghalu *et al*., (1993) that in environment where the temperature variation through the year is small and moisture availability is seasonal, the dry season leaf fall and wet flushing will occur to avoid seasonal moisture stress. The greatest monthly litter productions that occurred between the end of the rainy season and the beginning of the dry season, this period represents the beginning of a phase of high temperatures associated with torrential rain and strong winds usually interspersed with longer rainless period (Reinaldo and Philip, 1995)

The combination of these climatic factors when carefully considered could cause a greater litterfall rate during the period due to (1) physiological stimulation, with shedding of senile material to prepare for future investment in vegetative growth, or (2) mechanical breaking of plant parts. The input of rainfall intensity could have a greater ecological significance than the different rainfall variables (Brinkmann, 1985).

The lowest production of litter was found at the end of the driest month (March). This may be associated with high rate of Temperature. In tropical areas, the maximum use of solar radiation tends to be of great importance for primary productivity (Bray and Gorham, 1964), resulting in the plant making a greater investment in vegetative growth.

The negative correlation between mean monthly rainfall and total litter and leaf litter and similar trend recorded for maximum temperature suggests that total litter and leaf litter is strongly regulated by slight fluctuations in monthly rainfall and temperature.

REFERENCES

Aiboni V.U. 2001. Characteristics and Classification of soil of a representative topographical location in University of Agriculture, Abeokuta. Asset Series. 1(1): 51-61.

Anderson J.M. and Swift M.J. 1983. Decomposition in Tropical Forest. In: S.L. Sutton, T.C. Whitmore and A.C. Chadwick (Ed.) Tropical Rainforest. Ecology and Mgt. Blackwell, Oxford. pp. 287-309.

Bray J.R. and Gorham E. 1964. Litter production on the forest of the world. Advance Ecology Research. 2: 101-157.

Brinkman W.L.F. 1985. Studies on hydro biochemistry of a tropical lowland forest system. Geojournal. 11(1): 89-101.

Cecilia A.P., Juan J.A., Christian T. and Martin R.C. 2003. Litterfall dynamics and Nitrogen-use efficiency in two evergreen Temperate Rainforest of Southern Chile (internet materials).

Corinforth I.S. 1970. Leaf fall in a tropical rain forest. J. Ecology. 7: 603-608.

Cuevas E. and Medina E. 1986. Nutrient dynamics within Amazonian Forest ecosystems I. Nutrient flux in Fine litter and efficiency of nutrient utilization. Oecologia. 68: 466-472.

Dutta R.K. and Agrawal M. 2001. Litter fall, Litter decomposition and nutrient release in five exotic plant species planted on coal mine spoils. Pedobiologia. 45(4): 298-312.

Egunjobi J.K. and Fasheun F.E. 1972. Preliminary observations on the monthly litterfall and nutrient content of *Pinus caribea* leaf litter. Nigeria Journal of Science. 6(1).

Eklabya J.K. and Ambasht R.S. 1987. Litterfall, decomposition and nutrient release in an age sequence of *Alnus Nepalensis* plantation stands in the Eastern Himalaya. Journal of Ecology. 75: 997-1010.

Enright N.J. 1999. Litterfall dynamics in a mixed cornifer angiosperm. Forest in Northern New Zealand. J. Biogeog. 26: 149-157.

Facelli J.M and Pickett. S.T.A. 1991. Plant litter-its dynamics and effects on Plant Community structure. Bot. Rev. 57: 1-33.

Fassbender H.W. and Grimm U. 1981. Cidos biogeoquimicos en un elosisterma forestall de los Anoles occidentals de Venezuela II. Production is decomposicion de los residuos vegetables. Turrialba. 31(1): 39-47.

Herbohn J.L. and Congdon R.A. 1998. Ecosystems dynamics at disturbed and undisturbed sites in North Queensland Wet Tropical Rainforest III. Nutrient returns to the forest floor through litter fall. Journal of Tropical Ecology. 14: 217-229.

Hermansah A.Z, Tsugiyuki M., Toshiyuki. W. 2002. Litter fall and nutrient flux in tropical rain forest. West Sumatra, Indonesia 17th WCSS, 14-21Aug. 2002. Thailand. Symposium no 1125. paper no 1125.

Keay R.W.J. 1953. An outline of Nigeria vegetation. 2nd edition. Government Printer, Lagos.

Jackson J.F. 1978. Seasonality of flowering and leaf fall in a Brazilian subtropical lower montaine moist forest. Biotropica 10: 38-42.

Jones H.A. and Hockey R.D. 1964. The geology of part of South-Western Nigeria. Ministry of Mines and Power. Geological Survey of Nigeria Bulletin. (31): 101.

Lisanework N and Michelsen A. 1994. Litter fall and nutrient release by decomposition in three plantations compared with natural forest in the Ethiopian highland. Forest Ecology and management. 65: 149-164.

Lonsdale W.M. 1987. Predicting the amount of litter fall in forest of the world. Ann. Bot. (Lord). 61: 319-324.

Madge D.S. 1965. Leaf fall and litter disappearance in a Tropical Forest. Pedobiologia. 5: 273-288.

Muoghalu J.I, Akanni S.O. and Eretan O.O. 1993. Litter and nutrient dynamics in a Nigerian rainforest seven years after a ground fire. J. Vegetation Sc. 4: 325-328.

Nwoboshi L.C. 1981. Nutrient cycling in managed teak plantation ecosystem II. Litter fall and macro nutrient return to the forest floor. Nig. J. of Agric. Sc. 3(1): 9-14.

Odiwe A.I. and Moughalu J.I. 2003. Litter fall dynamics and forest floor litter as influenced by fire in a secondary lowland rain forest in Nigeria. Tropical Ecology. 44(4): 241-249.

Ola-Adams B.A. 1987. Effect of spacing on biomass distribution and nutrient of *Tectona grandis*. Linn F (Teak) and *Terminalia superba* Engls and Diels (Afara). Ph.D. Thesis. University of Ibadan, Ibadan.

Ola-Adams B.A and Egunjobi J.K. 1992. Effects of spacing on litter fall and nutrient content in stands of *Tectona grandis* Linn. F. and *Terminalia superba* Engls and Diels. African Journal of Ecology. 30: 18-32.

Ola-Adams B.A. 1978. Litterfall and disappearance in a Tropical moist semi-deciduous forest. Nig. Journal of Forestry 1 and 2: 21-26.

Proctor J. 1983. Tropical forest litterfall. Problems of data comparison. pp. 267-273. In S.L. Sutton, T.C. Whitmore and A.C. Chadwick (eds.). Tropical Rain Forest, Ecology and Management. Blackwell Scientific Publications, Oxford, U.K.

Regina M, Wetrington Braz, Delitt and Vana Stru FF aldi-De. Vuono. 1999. Litter and nutrient content in two Brazilian Tropical Forest. Revista Brasilenu de Botca. Vol. 22.

Reinaldo I.B. and Philip M.F. 1995. Carbon and Nutrient Flows in an Amazonian forest. Fine litter production and composition at Apiau, Roraima, Brazil.

Scarascia M.G., De Angelis P. and Sabatto M. 2000. A face experiment on short rotation, intensive popler plantation: Objective and experiment set up of POPFACE in Terrestrial Ecosystem Research in Europe. Successes, challenges and policy (eds. Sutton M.S., Moreno J.M., Von der Putter Witt *et al*.) pp. 139-140, Office of Official Publication of the European Communities, Luxembourg.

Temel S. 2003. Litter decomposition of *Picea orientalis*, *Pinus sylvestris* and *Castanea sativa* Trees crown in Artvin in relation to their initial title quality variables. Turkey 3. Agric. For. 27: 23-243.

Vitousek P.M. 1984. Litterfall, nutrient cycling and nutrient limitation in Tropical Forest. Ecology. 65: 285-298.

Vituosek P. and R.I. Sanfiord. 1986. Nutrient cycling in moist tropical forest. Annual Review of Ecology and Systematics.17: 1137-1167.

Yusheng Yany, Jiam Fen huo, Guang Sjui Chen Jin Shong, Xie Li Ping Cai and Peng Lin. 2004. Litterfall, nutrient return and leaf litter decomposition in four plantations compared with a natural forest in Tropical China. Am. For. Sci. 61: 465-476.