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LITTER PRODUCTION AND DECOMPOSITION OF DIFFERENT BAOBAB (*ADANSONIA DIGITATA* L.) STANDS IN A SAVANNA PARKLAND OF NORTHERN GHANA

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ABSTRACT

This study was conducted at Doba in northern Ghana with the aim of characterizing litter production and decomposition in relation to different natural baobab stands. Purposive sampling technique was used to select baobab trees based on three aggregation regimes of the stands: highly-clumped trees, moderately-clumped trees and isolated trees. Each stand type was replicated three times. In each stand category, four 1x1 m square litter traps were placed in the four cardinal directions under the tree canopies. The accumulated litter in each trap was collected at two-week intervals from January to December, a period of one year. Litter decomposition was carried out using the litter bags technique. Each stand category received a total of 30 nylon litter bags (10 x15 cm) with 1.0 mm mesh size. In each litter bag, 50g of litter was placed and the litter bags buried at a depth of about 20 cm randomly in each respective stand category and litter decomposition determined. The results showed that the total amount of litter produced in one calendar year under isolated, moderately-clumped and the highly-clumped stands were 3146.26gm^{-2}, 2963.04gm^{-2} and 3859.20 gm^{-2} respectively. The main litter components were leaf, flower, fruit, bark and twig. Litter decomposition varied significantly ($P < 0.001$) and the decomposition pattern in the three baobab stands showed an initial lag phase followed by rapid mass loss phase. However, litter decomposition in the highly-clumped stands was faster than those of the moderately-clumped and isolated baobab stands. The results further showed that the decomposition constants (k) obtained for the litter of the isolated and the highly-clumped stands were the same, while that of the moderately-clumped stand was slightly higher.

Keywords: Baobab, bark, decomposition, flower, fruit, leaf, litter.

INTRODUCTION

Baobab (*Adansonia digitata* L.) is a fruit-producing tree belonging to the family Bombacaceae. It has a massive trunk supporting a tangled mass of small branches (SCUC, 2006). It is a long-lived tree with multipurpose uses and the crown is usually compact, while the trunk tapers from top to bottom or is cylindrical or bottle-shaped (Sidibe and Williams, 2002). It occurs naturally as a scattered tree like many other Savanna woody species but some of them aggregate or grow together at certain sites, forming clumped vegetation which resembles relics of old forests standing in the parklands (personal observation). The tree is very important to the livelihood of the people in arid zones because it provides numerous products useful to man (Becker, 1983). It has an exceedingly wide range of uses, for instance, it provides food, shelter, clothing and medicine as well as materials for hunting and fishing (Venter and Venter, 1996; Gebauer *et al*., 2002). Almost every part of the tree is used, for example, fruits, seeds, tubers, twigs, leaves and flowers are identified as common ingredients in traditional dishes/medicine in rural areas (Nordeide *et al*., 1996).

Baobab is a typical deciduous tree which sheds its leaves during the dry season, especially in the Savanna parklands of the Upper East Region of Ghana, and litter fall represents a major biological pathway for elements transfer from vegetation to the soil. Mathews (1997) posited that litter production refers to plant materials shed in one year, consisting primarily of materials such as leaves, fine wood and fine roots. But measurement of litter production normally excludes large dead wood, coarse woody roots and fine roots, which implies litter measurements essentially reflect only aboveground litter production.

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Litter production by tree species is conveniently studied using litter traps, and according to Chapman (1976), a litter trap must fulfill the following basic requirements: the trap must intercept litter before it reaches the ground with little aerodynamic disturbance as possible; it must be designed or placed such that litter already on the soil cannot enter it; it must allow drainage of water without loss of litter, particularly fine litter; it must maintain trapped litter; and the size and number of litter traps used in any study must provide an estimate of the required degree of accuracy.

In general, litter production and decomposition are strongly interdependent. Juma (1998) defines decomposition as a biological process that includes the physical breakdown and biochemical transformation of complex organic molecules of dead material into simpler organic and inorganic molecules. Decomposition of plant litter is a crucial process in controlling the carbon balance of ecosystems and it is largely a biological process that occurs naturally and its speed is determined by three major factors, namely, soil organisms, the physical environment and the quality of the organic matter (Brussaard, 1994). Decomposition controls the release of important nutrients such as nitrogen, phosphorus and potassium, the availability of which affects the structure and functioning of plant communities (Bragazza *et al*., 2008). Litter decomposition is a complex process simultaneously affected by multiple chemical, physical and biological drivers. Thus, litter decomposition involves a complex set of processes, including chemical, physical and biological agents acting upon a variety of organic substrates that are by themselves constantly changing (Berg and McClaugherty, 2003).

It is widely acknowledged that an important factor affecting the rate of accumulation of organic matter in the terrestrial ecosystem is the rate of litter decay, but unfortunately, no completely satisfactory technique for measuring litter decomposition is yet available. Other things being constant, decrease of soil litter mass should be reflected in an increase in the organic matter content of the soil. Thus, a simple way to estimate decomposition rate is by measuring litter mass loss, an estimate typically obtained by means of litter bags, a technique used to study decomposition processes where plant litter is incubated and monitored over time. Although this method creates a microenvironment, it is easily used to study the dynamics of decomposition in samples of known initial weight which can be recovered in field conditions (Berg and Laskowski, 2006). The litter bag technique consists of confining litter in mesh bags that are placed on the ground and periodically collected so as to measure the remaining litter mass and associated litter chemistry (Singh and Gupta, 1977). This simple and cheap technique has been, however, criticized for the following: confined litter bags may create their own microenvironment different from surrounding bulk soil; litter bags may exclude specific faunal groups in relation to the mesh size (Nieminen and Setala, 1997; Bradford *et al*., 2002) and litter bags are usually filled with litter from a single species (Gartner and Cardon, 2004). Nevertheless, the litter bag technique is widely applied to monitor temporal mass loss in both terrestrial and aquatic environments.

In general, many litter production studies have been carried out in forest ecosystems and/or in plantations but there is paucity of knowledge on litter production in the Savanna areas, in particular reference to notable indigenous species like the baobab tree, on which very little is known about its general and reproductive phenology in literature as well. It is against this background that this study sought to characterize litter production and decomposition in relation to a basal area of baobab trees in a Savanna area to serve as baseline work for nutrient cycling study in the area.

MATERIALS AND METHODS

Study area

The study was conducted at Doba, a community near Navrongo in the Kasena-Nankana East district of the Upper East Region of Ghana. Doba is about 6 km southeast of Navrongo on the Bolgatanga-Paga main road. The community is located in the southeastern part of the district and shares boundaries with other communities such as Nayagnia, Kandiga, Janania and Wariga. The district covers a total land area of 1657 square kilometers in a Savanna zone and within latitude 10º 54' N and longitude 01º 06' W.

The vegetation of the area is Sudan Savanna with short grasses interspersed with common tree species like *Vitellaria paradoxa, Ceiba pentandra, Adansonia digitata* and *Parkia biglobosa* (Taylor, 1960). Agriculture and other human activities did not permit the establishment of a natural climax vegetation in this area, but fire pro-climax vegetation is predominant in the district with a few species of fire-tolerant trees growing over a continuous understory of grass cover (Blench, 1999).

The climate of the area is linked with the prevailing general air circulation affecting the West African sub-region. A clear-cut rainy season from May to October with a monomodal pattern and a dry season from November to April are the main features of the climate, but the onset of the rains is highly unpredictable. The mean annual rainfall is between 750 mm and 1100 mm, with high temperatures throughout the year. Also, the area experiences abundant sunshine throughout the year, with mean relative humidity values (measured at 0600 GMT) ranging between 35 and 95%. A climatic diagram of Navrongo, the nearest weather station is shown in figure 1.

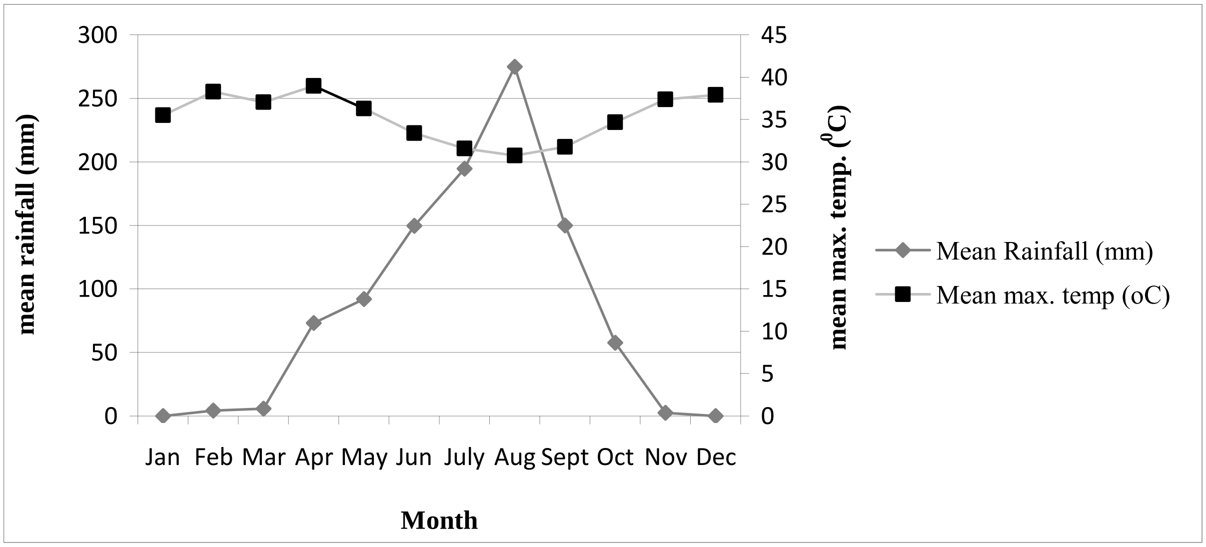

Fig. 1. A climatic diagram of Navrongo showing mean monthly rainfall and temperature patterns from 2001 to 2011. (Source of data: Ghana Meteorological Service).

A B

Fig. 2A. Litter traps in the neighbourhood of isolated baobab stand in the parkland. Fig. B. A litter trap showing collected litter under the canopy of a baobab tree.

Selection of experimental baobab trees

Purposive sampling technique was used to select baobab trees in the natural stands based on three aggregation regimes of the stands: highly-clumped trees, moderately-clumped trees and isolated trees. These classifications were based on results of tree inventory and reconnaissance survey carried out in the study area. Thus, highly-clumped baobab trees consisted of six trees situated within 20x20 m land area with closed canopy, while moderately-clumped trees were made up of three baobab trees situated within 20x20 m land area. Isolated baobab tree had no additional baobab tree within an area of 20x20 m of land area. One each of the baobab stand categories was identified at three different sites. Thus, each stand type was replicated three times.

Determination of litter production

Each stand category of baobab trees received four 1x1 m square litter traps placed in the four cardinal directions under their canopies, ensuring 100% canopy cover in all cases. The traps were left under the canopies throughout the dry and the wet seasons. The accumulated litter in each trap was collected at two-week intervals for a period of one year. The litter samples were brought to the laboratory and sorted into the following plant components: leaves; twigs; flowers; matured fruits; bark and miscellaneous component, which consisted of litter fragments that were difficult to be properly categorized. The samples were later dried in an oven at 80^{o}C for 48 hours (i.e., until a constant weight was achieved) and the dry weight of the plant materials determined with the aid of an electronic balance. Some litter traps in the neighbourhood of an isolated baobab stand (Fig. 2A & B).

Determination of phenophases of the baobab stands

The general phenology of the baobab trees in the three different stands, as well as other baobabs in the study area was closely monitored by regular field visits to document visible biological events that occur on the tree species. This was done by thorough visual examination for leaf drop, leaf flushes, time of flowering and fruiting.

Table 1. Mean litter production in the study baobab stands.

Lev. of aggr	Months	Litter components (gm^{-2})						
		Leaves	Floral parts	Matured Fruits	Bark	Twigs	Mis. Comp.	Monthly Mean
ISO	Jan	0	0	0	1.10±0.18	3.30±0.49	0.85±0.12	3.5±0.86
	Feb	0	0	0	0	0	2.22±0.59	1.48±0.6
	Mar	0	0	0	1.21±0.30	3.19±0.89	0	2.93±1.22
	April	0	0	0	0	2.18±0.25	1.32±0.10	2.33±0.63
	May	0	0	0	1.16±0.15	2.95±0.54	0	2.74±0.8
	Jun	1.97±0.09	0	0	1.50±0.10	2.32±0.42	0	3.86±0.73
	July	1.89±0.48	36.70±4.58	0	0	0	0	25.73±9.9
	Aug	5.70±1.32	90.44±38.56	0	0	0	1.39±0.22	65.02±24.27
	Sept	9.77±3.72	71.19±9.56	0	0	4.08±1.22	0	56.69±18.8
	Oct	60.33±11.3	9.40±1.50	107.90*	1.30±0.21	0	0.75±0.14	65.84±15.87
	Nov	262.31±7.98	4.38±3.58	124.08*	0	0	0	198.47±69.93
	Dec	139.49±4.64	0	0	1.88±0.22	2.30±0.32	0	95.78±37.74
	Totals	1925.84	848.44	231.98	32.60	81.28	26.12	3146.26
	Means	160.49±6.78	70.70±2.63	19.33±3.77	2.72±0.06	6.77±0.13	2.18±0.06	
MC	Jan	0	0	0	0.91±0.12	2.56±0.85	0	2.31±0.69
	Feb	0	0	0	1.08±0.06	2.18±0.11	0	2.17±0.61
	Mar	0	0	0	0	0	1.36±0.36	0.91±0.37
	April	0	0	0	0	2.24±0.43	0	1.49±0.61
	May	0	0	0	0	1.52±0.31	0.87±0.21	1.59±0.43
	Jun	1.47±0.33	10.49±4.44	0	0	2.24±0.83	0	9.47±2.73
	July	1.84±0.27	138.73±31.2	0	1.15±0.20	2.73±0.73	1.31±0.45	97.17±37.38
	Aug	2.04±1.16	65.68±10.74	0	0	0	1.53±0.44	46.17±17.69
	Sept	6.75±1.04	30.65±4.0	0	0	0	1.87±0.48	26.18±8.06
	Oct	25.41±5.99	12.99±4.29	0	1.2±0.22	0	0	26.4±7.02
	Nov	244.69±21.91	0	0	0	0	0	163.13±66.6
	Dec	173.43±15.53	0	0	0	1.84±0.12	0	116.85±47.1
	Totals	1822.52	1034.16	0	17.36	61.24	27.76	2963.04
	Means	151.88±6.81	86.18±3.48	0	1.45±0.05	5.1±0.1	2.31±0.06	
HC	Jan	0	0	0	0	3.25±1.29	0	2.17±0.88
	Feb	0	0	0	0	4.82±0.94	1.02±0.33	3.89±1.29
	Mar	0	0	0	0.89±0.12	5.54±2.39	0	4.29±1.48
	April	0	0	0	0.87±0.08	0	0.93±0.32	1.20±0.31
	May	0	0	0	0	2.77±0.74	0	1.85±0.75
	Jun	2.70±1.13	11.15±6.21	0	0	3.08±0.90	1.28±0.32	12.14±2.79
	July	4.96±0.32	63.13±19.13	0	0.83±0.10	0	0	45.95±16.92
	Aug	6.36±1.23	67.92±27.07	0	0	3.26±0.84	0	51.69±18.04
	Sept	4.88±0.16	38.34±5.53	0	0.80±0.15	0	1.06±0.31	30.05±10.14
	Oct	55.08±4.69	17.88±5.81	238.66*	0.98±0.33	0	0	89.07±18.71
	Nov	408.04±18.86	0	47.20*	0	4.47±2.42	0	282.87±110.21
	Dec	177.09±13.06	0	0	0	0	0	118.06±48.20
	Totals	2636.44	793.68	285.86	17.48	108.76	17.16	3859.20
	Means	219.7±10.20	66.14±2.14	23.82±5.75	1.46±0.03	9.06±0.18	1.43±0.04	

N.B: ISO = Isolated baobab stands, MC= Moderately-clumped and HC=Highly-clumped stands. Also, values with asterisk * represent collection from a single trap and not average values from the four traps.

Determination of the baobab stands litter decomposition

Litter decomposition studies were carried out in litter bags under the various categories of baobab stands by randomly collecting fresh samples of litter components from each stand and first sun-drying them in their respective stands. A total of 270 nylon litter bags (10x15 cm) with 1.0 mm mesh size were used in all. Litter bags of this mesh size have been used elsewhere with good results (Olofsson and Oksanen 2002; Scherer-Lorenzen *et al*., 2007). Under each stand category, 30 litter bags, each containing 50g of litter, were buried at a depth of about 20 cm to simulate conventional tillage practice used in the study area. The litter bags were retrieved every month for a period of seven months (i.e., May to November). The contents of retrieved litter bags were first emptied into clean containers and the litter cleansed of any soil particles and other non-litter debris. The litter was then

Table 2. Observed phenophases of the baobab trees in the study area.

Months	Leaf flush	Leaf fall	Flowering	Fruiting	Fruit fall
Jan	-	-	-	+	-
Feb	-	-	-	+	-
March	-	-	-	-	+
April	+	-	-	-	+
May	+	-	-	-	+
Jun	+	+	+	-	+
July	+	+	+	-	+
Aug	+	+	+	+	+
Sept	-	+	-	+	-
Oct	-	+	-	+	-
Nov	-	+	-	+	-
Dec	-	+	-	+	-

NB: Positive sign means presence and negative sign means absence of the process.

dried in an electric oven set at 80^{0}C for 48 hours (i.e., until a constant weight was achieved). The dry weight of the litter was then determined with the aid of an electronic balance and mass losses calculated.

Data Analysis

Data on litter production were analyzed using chi-square, while litter mass loss data were analyzed using a two-way analysis of variance (ANOVA). Also, decomposition rates were obtained by fitting a single exponential decay model to the changes of litter dry weight over time. For each baobab stand category litter, the decomposition rate constant, k, was calculated from the decay model described by Wieder and Lang (1982) as: $W_t = W_O e^{-kt}$, where W_t is the proportion of initial mass remaining at time t; k is the exponential decay coefficient; W_O is the initial mass remaining and t is time in days. The model was fitted with the restriction that at time = 0, all of the initial litter was present (Wieder and Lang, 1982) and with the stipulation that k-values could not be<0 (Wieder and Wright, 1995).

RESULTS

Litter production

The various litter components collected and identified during the experimental period comprised leaf, flower, fruit, bark, twig and miscellaneous. Litter production of the three baobab stands throughout the year showed a distinct seasonal pattern especially among the leaf, fruit and flower components. Total litter production varied markedly in different months and this depended on the leaf fall pattern of the baobab trees. For instance, when the trees were leafless from January to May, litter production was low and increased substantial from June towards the end of the year when the trees were in leaf. Thus, litter production under the baobab stands varied slightly in the various output but closely related to the phenological cycle of the tree species.

The total amount of litter produced in one calendar year under isolated, moderately-clumped and the highly-clumped stands together with the mean monthly litter produced throughout the year and the total mass of the different litter components under the three categories of baobab stands are shown in table 1. There were no significant differences (χ^2 = 13.745, df = 189, P = 1.000) among the leaf component of the litter produced under the various baobab stands. The highest average annual leaf litter produced under the three baobab stands was in the order: moderately-clumped to isolated to highly-clumped stands. The highest litterfall was recorded in the month of November for the three categories of baobab stands. Leaf litter was produced only in seven months of the year (see Table 1).

Similarly, there was no significant difference (χ^2= 7.855, df = 144, P = 1.000) among the flower component of the litter produced by the various baobab stands. The annual flower litter produced by the various baobab stands ranged between 4.38 ± 3.58 gm^{-2}and 138.73 ± 31.20 gm^{-2}, and these were produced within five months of the year.

However, there was significant difference (χ^2= 160.011, df = 111, P = 0.002) in bark litter produced by the various categories of baobab stands. The highest bark litter was produced by the isolated stands and the least by the moderately-clumped stands (Table 1). Period of bark litter production varied for the different stand types as follows: six months in isolated stands, four months in moderately-clumped stands and five months in highly-clumped stands.

Similarly, there were significant differences (χ^2= 287.715, df = 165, P = 0.001) among the twig litter produced under the three baobab stands. The highest twig biomass was produced by the highly-clumped stands, followed by isolated stands while moderately-clumped stands produced the least (Table 1).

Table 3. Percent mass loss of baobab litter in the study stand categories.

Baobab/Months stands	April	May	June	July	Aug	Sept.	Oct.	Nov.
Isolated baobab stands	100 ± 0	1.90 ± 0.09	3.92 ± 0.29	10.98 ± 1.23	30.04 ± 1.39	49.74 ± 0.89	66.54 ± 0.34	84.02 ± 0.28
Moderately-clumped stands	100 ± 0	1.28 ± 0.02	3.62 ± 0.04	14.48 ± 0.58	28.20 ± 1.21	45.82 ± 1.51	63.88 ± 1.50	82.00 ± 1.09
Highly-clumped stands	100 ± 0	1.54 ± 0.17	4.08 ± 0.55	10.32 ± 1.31	28.20 ± 3.13	57.98 ± 1.77	78.68 ± 0.64	90.08 ± 0.29

Table 4. Parameters of the single exponential decay model.

Baobab Stands	Actual 50% mass loss time (Days)	Nat. log of mass loss of litter-time graphs gradient	Calculated K from the single Decomposition Equation	Developed Mass loss Relation for Baobab litter
Isolated baobab stands	153	0.0096	0.0529	$y = 50e^{-0.0529x}$
Moderately-clumped stands	156	0.0088	0.0533	$y = 50e^{-0.0533x}$
Highly-clumped stands	141	0.0154	0.0529	$y = 50e^{-0.0529x}$

The results also indicated that the miscellaneous component of litter produced did not differ ($\chi^2 = 20.697$, df = 102, P = 1.000) among the three stand categories.

Phenological cycle of baobab trees in the study area

The results of the phenological study are summarized in table 2. The results indicate that within one calendar year in the study area, the baobab tree defoliates completely once at the peak of the dry season (i.e., December/January) and foliates again during the rainy season (i.e., June to October). It also flowers once from June to August and fruits once from September to February. The tree species usually sheds all its leaves by December and remains without leaves for at least two to three months and then begins leaf flushes around April/May and by the rainy season (i.e., July to October), it is in full leaf again. The results thus indicated that leaf flushes of the trees begin around March/April and leaf fall commences around October/November, while flowering and fruiting occur in May/June and June/July, respectively.

Litter mass loss of the baobab stands

The results of the study on baobab litter mass loss in the various stand categories are summarized in table 3. Litter mass loss varied significantly ($P < 0.001$) with the highly-clumped category showing the greatest mass loss and the moderately-clumped category the least. Litter mass loss was slow within the first two months of incubation, becoming rapid afterwards until the end of the experimental period, and this pattern was similar for all the stand categories.

Litter decay constant (k) from the single exponential decay model

The results showed that the litter decomposition constants (k) obtained using the relationship developed by Wieder and Lang (1982) were the same for the isolated and the highly-clumped stands, while that of the moderately-clumped stand value was slightly higher (Table 4). In addition, the values obtained from the gradients of the graphs of natural logarithm of the various baobab litter mass of residue remaining against time for the three categories of stands showed slightly different values (constants). The values obtained from the graphs were slightly lower than the corresponding decomposition constants obtained from Wieder and Lang (1982) relationship, indicating that a single relation can be used to determine litter mass loss for both the isolated and highly-clumped stands, while a similar but slightly different relation can be used for the moderately-clumped stands litter (Table 4).

The results also indicated that the actual 50 % mass loss time for the litter of the three baobab stands was in the order: moderately-clumped > isolated >highly-clumped stands (Table 4). The results thus showed that 50% of litter from highly-clumped stands decayed 141 days after incubation, while 50% of the litter from the isolated stands decayed after 153 days of incubation. Similarly, 50% of the litter from the moderately-clumped stands decayed within 156 days of incubation.

DISCUSSION

Litter production in the study baobab stands

According to several reports (Haase, 1999; Sundarapandian and Swamy, 1999; Norgrove and Hauser, 2000; Yang *et al*., 2004), litter production in general depends on several factors such as climate, species composition, stand age and litter quality. It is therefore difficult to compare figures from different studies. Additionally, information on baobab litter production is not available to afford a direct comparison with the findings of this study. Thus, an attempt will be made to compare the findings in this current study to related issues in other studies. In general, the monthly variation in litter mass depended on the leaf fall pattern of the baobab trees. Leaf litter production peaked in November and was completely absent from January to April/May when the trees were leafless. Gebauer *et al.* (2002) reported that the baobab tree has been in leaf for four months and leafless for eight months in a year in Sudan in contrast with the findings of this study which indicate that the baobab tree is in leaf for about seven months. These differences may be attributed to differences in climatic and other aforementioned factors by Haase (1999), Sundarapandian and Swamy (1999), Norgrove and Hauser (2000) and Yang *et al.* (2004).

The results in this study indicated that the main components of litter of the three baobab stands were produced in the wet season and these components of litter production quickly commences after the onset of the rains when the trees were foliated and increases towards the transition between the wet and dry season. In other studies, the maximum litter production has been attributed to factors like water stress during hot, dry periods (Lugo and Snedaker, 1974), increased precipitation (Pool *et al*., 1977) and wind (Sasekumar and Loi, 1983). Also, Wieder and Wright (1995) reported that litter fall generally occurs during the whole year and can even peak during the rainy season in the case of unusually severe windstorms. Other evidence indicates that litter production might be related to tree height or other aspects of stand structure. For example, Woodroffe *et al*. (1988) reported that litter fall of tree stands exceeding 10 m in height was 8 ton $ha^{-1}yr^{-1}$, while production from smaller trees was considerably less than 3 ton ha^{-1} yr^{-1}. The baobab trees in the three stand types were of similar height (see Imoro and Barnes, 2013) and this probably accounted for the similar litter production with respect to the main litter components under the three baobab stand types.

Phenological cycle of baobab trees in the study area

The flowering phenology of the baobab trees in the parklands at Doba in the Upper East Region of Ghana indicates that the tree species normally flowers from June to August every year. This finding contrasts with Baum (1995) who reported different flowering periods of baobab trees in different locations in Africa: October to December in South Africa; November to December in Madagascar; May to June in West Africa, and in Sudan, flowering of baobab occurred sporadically throughout the year except in the peak dry season (January to March). Sidibe and Williams (2002) posited that timing of flowering in baobab trees differs between geographically isolated populations. Thus, the difference in the period of flowering in the current study and that of Baum (1995) is probably due to different study locations with their concomitant differences in environmental and other site-specific conditions. Phenology of tree species in general depends on many variables including climatic conditions and the genetic make-up of the species.

In this study, fruiting and maturing times of baobab trees span over a period of seven months, from August to February. Sidibe and Williams (2002), however, found that baobab fruits develop five to six months after flowering in some parts of West Africa.

Litter mass loss of the baobab stands

The study showed an initial slow mass loss, especially during the phase corresponding to the dry periods in the study area, followed by a fast rate of mass loss. The rapid rate of litter mass loss after the initial lag phase could be attributed to the net effect of a large number of processes, notably, increased utilization of readily available energy sources by microbes, loss of water-soluble components from the litter and increase in moisture levels in the environment, which naturally enhance the process of decomposition. In many decomposition studies, a rapid mass loss stage is followed by a decline, which is normally attributed to the presence of recalcitrant fractions like cellulose, lignin and tannins in the litter, but this latter phase was not found in the present study. This disparity might be attributed to low concentrations of these recalcitrant materials in baobab litter. For example, Andy and Eka (1985) reported low levels of tannins in baobab leaves of 17.8 mg/100 g and 19.8 mg/100 g from market and field samples respectively.

Generally, the decomposition rate of litter is influenced by its physico-chemical properties such as its content of lignin and other phenolic compounds, lignin/nitrogen ratios, C/N ratios, physical leaf toughness and physical barriers on the leaf surface, as well as the composition of soil organisms and microclimate conditions (Swift *et al*., 1979; Hattenschwiler and Vitousek, 2000). Thus, the variations in litter decomposition rate observed in the current study could be attributed to micro site heterogeneity with respect to soil organisms and other microclimate conditions, since the litter used was obtained from the same species in the same ecological area, and is likely to have similar physico-chemical properties.

Litter decay constant

The similarity in decomposition constant (k) for the litter in the isolated and highly-clumped stands calculated using Wieder and Lang's (1982) formula might have resulted from the fact that the litter was obtained from the same plant species and probably the micro site conditions and soil organisms that cause decomposition operated at the same levels at both sites. At the moderately-clumped site, however, differences in these parameters, especially micro site conditions might have accounted for the different decomposition constant, since the species are the same, and, therefore, the litter is likely to possess similar physico-chemical properties as that of the other stand types.

CONCLUSION

The litter produced by the three different baobab stands were categorized into leaf, flower, fruit, bark, twig and miscellaneous fractions. Among these, leaf litter was produced within seven months of the year and the highest litter fall was recorded in the month of November in all the three categories of baobab stands. Also, flower litter was produced within five months of the year and the average flower biomass produced was in the order: moderately-clumped > isolated > highly-clumped stands. The highest twig biomass was produced by the highly-clumped stands and the least by the moderately-clumped stands. Furthermore, the litter decomposition (mass loss) of the three baobab stands showed an initial slow rate (for approximately two months) for all the three categories of baobab stands, but after this period, a rapid mass loss occurred until the end of the experimental period. In addition, the decomposition constants (k) obtained for the litter for the isolated and the highly-clumped stands were the same, while that of the moderately-clumped stands was slightly higher.

RECOMMENDATION

The study recommends further work to determine quantitative and qualitative levels of nutrient inputs by baobab litter as well as its cycling in order to highlight its ecological role in the Savanna ecosystem.

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