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CANOPY MANAGEMENT, LEAF FALL AND LITTER QUALITY OF DOMINANT TREE SPECIES IN THE BANANA AGROFORESTRY SYSTEM IN UGANDA

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ABSTRACT

Small-scale farmers in the banana-coffee agro-zone of Central Uganda plant and maintain trees to provide a range of benefits. However, the impact of trees on soil fertility and crop yields is small. On many farms, trees exist in infinite numbers, compositions, with no proper spacing, sequencing and canopy management recommendations. The objectives of this study were to: quantify and compare leaf fall and leaf litter biomass for the dominant tree species subjected to different pruning regimes and during different seasons and determine the nutrient concentrations in leaf litter materials in order to assess their potential to improve soil fertility. A survey was conducted on 30 randomly selected farms to examine and document the tree species. Four tree species were dominant; *Ficus natalensis* (15.3%), *Albizia coriaria* (10.2%), *Artocarpus heterophyllus* (10.0%) and *Mangifera indica* (9.2%). Experiments such as canopy pruning, collecting leaf fall and weights of pruned leaf biomass were established for the four dominant trees on five randomly selected farms. A total of 120 trees were subjected to three pruning regimes (0%, 25% and 50%). Litter traps (1 m × 1 m) were placed 2 m from the tree trunk to collect falling leaves. Leaf biomass was collected from pruned branches and weighed. Leaf samples were collected from pruned leaves and a composite sample analysed for carbon and nutrient concentrations. Results showed that 40 tree and shrub species belonging to 21 families existed on farms. Leaf fall was highest in the dry season and *A. Heterophyllus* registered the highest amount. Leaf biomass from pruned trees was heaviest for *M. indica* (42.4 ±3 kg) in the wet season and at the 50% pruning regime (45.7± 2.1kg). Total nutrient concentrations were in the order *A. coriaria*>*F. natalensis*>*A.heterophyllus*>*M.indica*. We concluded that *F. natalensis* and *A. Coriaria* should be integrated more into the agroforestry system to improve soil fertility. *A.heterophyllus* and *M.indica* should be planted on farm boundaries. The 50% pruning regime was the best and should be carried out during the wet season.

Key words: Tree species, canopy management, leaf fall, nutrient concentrations, soil fertility

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INTRODUCTION

Poor soil fertility is a major challenge affecting banana production in Uganda [1]. Inherent low soil fertility with Oxisols covering about 70% of Uganda's land area, coupled with continuous cultivation with little or no efforts to replenish the lost macro nutrients has resulted into accelerated nutrient depletion [2, 3]. Consequently, highland banana yields especially on smallholder farms are low 5–30 Mg ha^{-1} yr^{-1} and productivity continues to decline [4, 5]. Yet the banana potential yield is estimated at 100 Mg ha^{-1} [6] and attainable yields of 70 Mg ha^{-1} yr^{-1} have been reported on a farm in south western Uganda [7], indicating a large yield gap. But food demand is predicted to increase given an annual population growth rate of 3%, with the youth constituting about 80% of the population [8, 9]. Banana is a staple food for over 10 million Ugandans in a total population of 38 million and number continues to grow with increasing urbanization. This implies that banana productivity has to be increased in order to keep pace with the increasing demand.

Research efforts to increase productivity of the banana systems have traditionally focused on a number of strategies such as intercropping, mulching, use of cover crops, application of mineral fertilizers and /or organic manures [2, 10]. Few farmers in Uganda use mineral fertilizers [11], with rates applied among the lowest in the world (<10 kg of nutrients $ha^{-1}yr^{-1}$). The quantities of organic materials available from common pool areas have reduced over the years due to population pressure [12], hence these materials cannot be exclusively used to improve soil fertility. Under the plan for modernization agriculture, a government of Uganda supported agricultural productivity enhancement program, government fully recognizes low soil fertility as a national concern, with a focus on locally manufacturing fertilizers such as triple super phosphate (TSP) from the available rock phosphate deposits in eastern Uganda. But the soil fertility – crop yield nexus continues to be complicated by emergent issues such as climate change, hence a need for a more integrated and feasible approach to productivity enhancement.

In trying to address soil fertility challenges, small scale farmers use various methods one of which is the integration of trees and shrubs (agroforestry) into farming systems as a plausible option for improving or sustaining soil productivity [13, 14]. Trees as components of an agroforestry system improve soil fertility through leaf litter fall, which is broken down to release nutrients. The improvement in soil fertility is often associated with leaf litter quality, the nutrient concentrations in leaf tissues and the decomposition rates [15]. However, agroforestry may not always provide a feasible solution as negative interactions may occur due to light competition with the below growing crops [16, 17], hence reducing the adoption rates for the agroforestry approaches. Some tree species such as *Senna spectablis, Senna siamea, Spathodea campanulata, Milicia excelsa* and *Markhamia lutea* were reported to have negative effects on soils [18]. This may be attributed to poor litter quality and exudates, which may affect the activities of the soil invertebrate population.

On smallholder farms in Uganda, different tree and shrub species exist in infinite numbers and compositions with no proper spacing, sequencing and canopy management recommendations resulting into limited benefits and thus low crop yields [19]. This study

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was conducted to: (i), quantify and compare leaf fall for the dominant tree species at different pruning regimes and during different seasons (ii), quantify and compare leaf litter biomass for the dominant tree species under different pruning regimes and during different seasons and (iii), determine nutrient concentrations and organic carbon in leaf litter materials in order to assess their potential for soil fertility improvement.

MATERIALS AND METHODS

Study area

This study was conducted in Kiboga District, Uganda (1°30'N and 32°14'E) which is located in the banana-coffee agro-ecological zone. The soils are predominantly reddish-brown Ferralsols that exhibit a fine, porous and granular structure. They have low water holding capacity, low nutrient content and base saturation [20]. Rainfall is bimodal (1000−1200mm per annum) with the first season occurring in mid-March to June, and the second from August to November. Daily maximum temperatures are 18−35°C, and the minimum temperatures 8−25°C. Crop farming and animal rearing are the most important economic activities. The dominant crops and fruit trees include: bananas, coffee, beans, cassava, maize, sweet potatoes, cabbages, pineapples, tomatoes, mangoes, jack fruits, pawpaw, passion fruits and onions [21].

Profiling tree species in the banana agroforestry system

Lwamata sub-county was purposively selected for this study because of the traditional agroforestry practice. Five villages (Kisweeka, Kiryamuddo, Nabuzaana, Buyira and Nabyoto) were randomly selected. Thirty (30) banana agroforestry farmers (6 per village× 5) were randomly selected from the village registers and used for tree profiling. At each farm in the plantation, a 10m × 10m quadrat was demarcated using a sisal string from the farm boundary to cover the whole farm, which was a modification of 5m × 5m quadrat used by Nantale *et al.* [22]. This was because of the bigger size and larger spacing of the banana plants (3m × 3m) as compared with the spacing of other crops such as maize (0.75m ×0.25m). Using transect walk and observation techniques [23, 24] with the guidance of the host farmers, all trees and shrubs taller than three meters within the quadrats were recorded. The four (4) most common tree species in the banana-agroforestry systems were determined and used for experimentation.

Canopy management experimentation and leaf biomass determination

Five (5) farmers (one per village) were randomly selected from the 30 farmers to host the on-farm experiments for tree pruning and leaf litter fall. At each experimental site or farm, 24 trees (3 trees × 4 most dominant species ×2seasons - wet and dry) were randomly selected and marked. Each tree species per site was subjected to three different pruning regimes: 0%, 25% and 50% pruning regimes. A total of 60 trees were used in each of the two seasons' experiments (60 × 2) conducted during the rainy season (April to June) and during the dry season (January to mid- March). In order to retain canopy diameter (size) and crown shape but reduced canopy density, crown thinning was done when pruning trees [25, 26]. To attain the 25% and 50% canopy pruning regimes, all secondary branches on a tree under investigation were counted and divided by four and two, respectively. Thereafter branches to be pruned were randomly selected, labeled by making slit cuts and later pruned using three cut procedure adopted from Bedker *et al.*

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[25] to avoid splitting and damage during pruning. Pruning was done using hand saws, cutting as close to the stem as possible. Leaves from all the pruned branches were stripped off, dried under shade for 14 days and weighed to determine the leaf biomass.

Leaf litter fall, collection and measurement

Leaf litter fall was collected from the three pruning regimes (0%, 25% and 50%) using the litter trap technique [14, 27, 28]. To collect the falling leaves, a 1m × 1 m trap was constructed from a strong nylon mesh suspended on a frame of four wooden pole stands erected, 0.90m above the ground (Figure 1). One litter trap was randomly placed two meters from the tree trunk. The litter fall traps for all the 60 trees in a season were set on the same date to avoid the effect of temporal variations on the collected leaf litter materials.

Figure 1: A litter trap (1 m × 1 m) and 0.9 m high constructed using locally available materials used to collect falling leaves from the dominant tree species in the banana agro-forestry system in Uganda. The trap was established two meters from the tree trunk

Collection of fallen leaves from the litter traps was done at 14, 28, 42 and 56 days from the date of establishing the litter traps, a modification of the monthly collection interval used by Muzoora [14], Triadiati *et al.* [28] and Gupta *et al.* [29]. The shorter interval was to ensure that all the leaves falling on the trap are collected, thus minimizing effects of wind (leaves blown off the trap). At each collection, only the leaf litter of the tree species under consideration were sorted and put in labeled polythene bags indicating the tree species and pruning regime. All leaves from the non-target trees were discarded. Collected leaves were dried under shade for 14 days to a constant mass. The dried leaves were weighed using a spring hanging scale pesola (measuring range 0–30g and accuracy ±0.3%) band the weights reported in g m^{-2}.

Leaf analysis for nutrient concentrations and organic carbon
Composite samples of leaves from both natural fall and pruning were collected from the four dominant tree species from each of the five sites, kept in labeled polythene bags and dried under shade for 14 days. Laboratory analysis was done at the National Agricultural Research Laboratories Institute soil science laboratory to determine total nitrogen (N), total phosphorus (P), total potassium (K), calcium (Ca), magnesium (Mg) and the organic carbon content. Leaf samples were oven dried at 72°C for one day, crushed to 0.06mm, sieved and digested at 330°C using a sulphuric acid/selenium digestion mixture. Total nitrogen (N) was determined by a modified Kjeldahl method because of its suitability for diverse litter, soil types, and pH [30]. The phosphorus concentration was determined using the colorimetry method and calcium (Ca) and magnesium (Mg) concentrations by the Atomic Absorption Spectrophotometer (AAS). Potassium (K) concentrations were determined using the flame photometer. Organic carbon was analyzed by combustion in a muffle furnace. Ten grams (10g) of well mixed air-dry leaf sample (< 2mm) of known moisture content was weighed into a dry Nickel crucible. This was heated slowly in a furnace raising the temperature setting in three steps (100°C, 200°C and 500°C). The final temperature setting of 550°C was maintained for eight hours. The crucible containing a grey- white ash was removed, cooled in a desiccator and weighed. The loss in weight represented the moisture and organic matter of the sample while the residue represented the ash.

Data analysis
Analysis of covariance (ANCOVA) model was used to determine the interactions between seasons, pruning regimes and sampling period (fixed factors) and leaf fall (covariate). Before data were analysed, they were tested for normality and those which were not meeting the statistical assumptions were subjected to the appropriate transformations, leaf litter fall - log(x+1) and dry weight of litter – log (x). Analysis of variance (ANOVA) was then performed with general linear model (GLM) procedure. Means were separated by Tukey's test at 5% level of significance. In addition, leaf fall across seasons and pruning regimes were compared by unequal pair-wise t-test with degrees of freedom estimated by Satterthwaite's method. All the analysis was done using SAS software [31].

RESULTS

Tree species in the traditional agroforestry system
A total of 1558 trees and shrubs belonging to 40 tree and shrub species and 21 families were encountered and documented from the 30 banana farms that were surveyed. Fabaceae (22.5%), Moraceae (20.0%), Myrtaceae (7.5%), Bignoniaceae and

Euphorbiaceae (5.0%) were the most prevalent families observed. Further, *Ficus natalensis* (15.3%), *Albizia coriaria* (10.2%), *Artocarpus heterophyllus* (10.0%) *and Mangifera indica* (9.2%) were the most prevalent tree species recorded.

Effect of season, pruning regime and sampling period on leaf litter fall for the selected trees

Leaf litter fall varied significantly across the selected tree species in both dry and wet seasons. The highest mean leaf litter fall was recorded underneath *A. heterophyllus* (7.8±3.4g) and *M. indica* (7.8±2.9g) in the dry season and underneath *A. heterophyllus* (5.4±2.8g) in the wet season. Significantly more leaf litter fall was produced in the dry than wet season irrespective of the tree species (Table 1).

Leaf fall varied significantly ($P \leq 0.05$) across the pruning regimes in both the dry and wet seasons. As expected, the highest leaf fall in the dry (9.7±2.8g) and wet season (6.3±2.1g) was recorded under the 0% pruning regime. Leaf fall was significantly higher in the dry than wet season (Table 1).

Leaf litter fall varied significantly across the sampling periods in both dry and wet seasons. The highest leaf litter falls (7.7±3.4g and 4.8±2.2g) were recorded in the dry and wet seasons, respectively at 56 days sampling period. Similarly, leaf litter fall was significantly higher in the dry than wet season at all the sampling periods (Table 1).

Effect of seasons and pruning regime on dry weight of pruned leaf litter

The dry weight of the pruned leaf litter varied significantly ($P \leq 0.05$) across the tree species in both dry and wet season. The heaviest leaf litter was obtained from *M. indica* (37.1±4.1kg and 42.4±3.4kg for dry and wet seasons respectively). On the other hand, the pruned leaf litter was heavier in wet than dry season but not significantly ($P > 0.05$) different (Table 2).

The dry weight of the pruned leaf litter varied significantly across the tree species under both pruning regimes. The highest dry weight of pruned leaf litter was recorded from *M. indica* (39.9±4.1 and 45.7±2.1kg) for 25% and 50% pruning regimes, respectively. Similarly, the pruned leaf litter was significantly higher under 50% than 25% pruning regimes in the dry (29.8±9.7 kg) and wet (31.8±10.6 kg) seasons for all the dominant tree species. Significantly higher leaf litter was obtained in the wet (23.9±8.8 kg) than in the dry (18.8±7.8 kg) season for the 25% pruning regime but not for the 50% pruning regime (Table 2).

Nutrient concentrations in the litter of the dominant tree species

The Carbon to Nitrogen (C:N) ratios were in the order: *M. indica (4.31)>A. heterophyllus (4.11)>A. coriaria (3.80) >F. natalensis (3.29).* The Nitrogen concentrations were in order: *A. heterophyllus* (3.7%), *F. natalensis* (2.4%), *A. coriaria* (2.2%), and *M. indica* (1.6%). The highest concentration of the other nutrients was recorded in: *A. coriaria* leaf litter, that is, P (0.2%), K (1.3%), Ca (1.2%) and Mg (0.8%)- (Table 3).

DISCUSSION

Tree species in the banana agroforestry system

Results showed that an average of 51 trees and shrubs per farm were intercropped with banana. These findings are similar to those of other studies in Uganda such as Muzoora [14] who observed that growing of trees with other crops is common on smallholder farms in Uganda due to provision of a range of benefits to households. Sebukyu and Mosango [32] also noted that several tree species are intercropped with different banana cultivars in the traditional banana cropping systems of central Uganda. Fabaceae, Moraceae, Myrtaceae, Bignoniaceae and Euphorbiaceae were the dominant families whereas; *Ficus natalensis*, *Albizia coriaria, Artocarpus heterophyllus and Mangifera indica* were the commonest tree species. These tree species were reported to be the dominant in agroforestry systems in central Uganda [32, 33, 34]. The high prevalence of these tree species in the agroforestry systems was attributed to factors such as drought tolerance, the ability to regenerate naturally, being easy to manage, maturing fast, and easiness of their propagation [34]. However, the occurrence of *Artocarpus heterophyllus* (Jack fruit) and *Mangifera indica* (Mango tree) on farms is also attributed to their contribution as sources of food and income. *Ficus natalensis* and *Albizia coriaria* have small easily decomposable leaves, which are also used as fodder for animals. In this regard, the occurrence of particular trees on farms based on decisions made by farmers should be used as a basis for promotion of tree planting in the banana agroforestry system.

Leaf fall and pruned leaf biomass

Leaf litter fall was found to be influenced by season and was highest in the dry season (Table 1). This concurs with the findings of Barlow *et al.* [35]. In this study, the higher leaf fall in the dry season as compared to the wet season could be related to leaf senescence, low precipitation/drought, low atmospheric humidity, high wind speed and temperature [c.f. 28, 29, 36, 37, 38]. Leaf litter fall is a key process in the dynamics of agroforestry ecosystems, being a linkage between the tree and soil nutrient pool and, therefore, the starting point for nutrient cycling [39]. Therefore, knowledge of these processes is essential for sustainable management of agroforestry systems and would be very important for soil fertility management in the banana agroforestry systems.

Weight of leaf litter fall varied across the dominant four tree species with *A. heterophyllus* and *M. indica* having the highest weight registered in the dry season (Table 2). Differences in leaf biomass that is size and number [29, 40], tree crown architecture and phenology [38, 41] amongst tree species are some of the factors found to influence amounts of leaf fall. The higher amounts of leaf fall registered in the dry season as compared to the wet season could be attributed to harsh climatic conditions of high temperatures, wind speed, low precipitation, low soil moisture and atmospheric humidity that increase natural leaf senescence [27, 28, 41, 42]. Leaf litter-fall was noted to have decreased with increasing pruning intensity for all the selected tree species (Table 2). Pruning reduces the above ground biomass and thus the amount of leaf litter produced [38]. Pruning of branches also reduces the number of buds from which new branches and leaves are formed therefore diminishing overall photosynthesis of pruned trees [36]. Litter production and weight of pruned leaf weights has been found to vary because of tree phenology [38]; tree species' architecture, tree age and local environmental conditions [43]. Differences in litter quality, varying amounts of water soluble phenolic compounds, flavonoids, tannins, physicochemical properties of litter and the presence of thick cuticle among tree species have been cited to influence litter production and weight of pruned leaves [44].

In all the selected tree species, the 50% pruning regime registered the highest dry weight of pruned leaf biomass in both wet and dry seasons, with *M.indica* registering the highest weight while *A.coriaria* had the lowest. The 50% pruning regime had the highest number of pruned branches hence the highest volumes of leaf mass obtained. However, the dry weight of leaves varied with the dry season having lower weight as compared to the wet season. This reduction in weight in the dry season as compared to the wet season could be attributed to the increased natural leaf fall that is induced by increased natural leaf senescence [27, 28, 42].

Nutrient concentrations in the leaf litter materials

Nutrient concentrations of leaf litter differed significantly across the selected tree species (Table 3). Variations in foliar organic carbon and nutrient concentrations, amount of leaf litter produced and canopy structure [29], and soil nutrient status [43, 45] have been reported to influence the overall potential of tree species to improve soil fertility. In this study, leaf litter from *A. coriaria* and *F. natalensis* had the lowest C:N ratios and higher concentrations of nitrogen, potassium, calcium, magnesium and phosphorus as compared to the other tree species. For C:N ratios of above 30, net nitrogen immobilization occurs while net nitrogen mineralization begins when C:N ratios fall below 15 [14]. Higher nitrogen and phosphorus concentrations in litter usually lead to faster decomposition [36]. Hence *A. coriaria* and *F. natalensis* leaf litter have a higher potential to release nutrients to improve soil fertility in the banana agroforestry system. Despite the better total litter nutrient status for *A. coriaria* and *F. natalensis*, the amount of litter produced from the pruned braches was lower due to the small leaf size. From this study, *A. coriaria* generated 20 kg of leaf litter after pruning. Assuming 50 trees per hectare (at a spacing of 9 m × 9 m), 1 Mg of litter will be generated adding 22 kg N, 2 kg P, 13 kg K, 1.2 kg Ca and 8 kg Mg, in addition to nutrients added through litter fall and nutrients from other sources. Farmers should be encouraged to plant more of *A. coriaria* and *F. natalensis* in order to generate more litter on-farm.

CONCLUSION

Forty tree and shrub species belonging to 21 families were found in the banana agroforestry cropping system of Kiboga district in Uganda with *F. natalensis, A. coriaria, A. heterophyllus and M. indica* being the most prominent species. However, there is need to determine the best spacing patterns for these tree species based on canopy structure. This will reduce over shading as tree canopy pruning is still a rare practice in the banana agroforestry cropping system.

Leaf litter fall was influenced by season and was highest in the dry season. Weight of leaf litter fall varied amongst the dominant four tree species with *A. heterophyllus* and *M.indica* having the highest weight registered in the dry season. As expected, leaf litter

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fall decreased with increasing pruning intensity for all the dominant tree species. In all the tree species, the 50% pruning regime registered the highest dry weight of pruned leaf biomass in both wet and dry seasons, with *M. indica* registering the highest weight while *A.coriaria* had the lowest. Therefore, canopy pruning should be done in the wet season and at 50% pruning regime where higher leaf biomass is produced for organic matter and soil fertility enrichment. However, since canopy pruning is gender sensitive, women are unable to carry out this practice. Under such circumstances, there is a need to quantify the labor costs and possible damage to crops by the pruned branches. A complete benefit-cost analysis study will increase the adoption rates for this practice.

Nutrient concentrations of leaf litter differed significantly across the selected tree species. Leaf litter from *A. coriaria* and *F. natalensis* had the lowest C:N ratios and higher concentrations of nitrogen, potassium, calcium, magnesium and phosphorus as compared to the other tree species. *F. natalensis* and *A. coriaria* should be integrated more in banana plantations. *A. heterophyllus* and *M. indica* should be integrated in a spatial pattern or on boundaries of banana gardens or farmlands to provide leaf litter (the cut and carry system) as a source of mulch or animal feed. The manure produced by the animals can then be used to improve soil fertility.

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Table 1: Mean ±SD leaf fall (g m^{-2}) from the dominant four tree species subjected to three pruning regimes at different sampling periods during different seasons in Kiboga district, Central Uganda

Tree species/regime/period	Season		P value
	Dry	Wet	
Tree species			
Albizia coriaria	4.4±1.7 bA	2.5±1.7 Bb	<0.0001
Artocarpus heterophyllus	7.8±3.4aA	5.4±2.8 Ab	<0.0001
Ficus natalensis	7.1±2.8aA	4.5±1.9 Ab	<0.0001
Mangifera indica	7.8±2.9aA	4.5±2.0aB	<0.0001
CV	17.88	27.15	
Pruning regime			
0%	9.7±2.8aA	6.3±2.1aB	<0.0001
25%	6.2±2.1bA	3.6±1.8bB	<0.0001
50%	4.4±1.6 cA	2.7±1.4cB	<0.0001
CV	14.51	26.12	
F value	116.75***	70.26***	
Sampling period (days)			
14	5.8±2.6bA	3.7±2.5bB	<0.0001
28	6.5±2.8bA	4.0±2.4 abB	<0.0001
42	7.0±3.2abA	4.4±2.3abB	<0.0001
56	7.7±3.4aA	4.8±2.2aB	<0.0001
CV	19.98	32.50	
F value	4.06**	2.63*	

Same letters within a column (small letters) and row (capital letters) indicate means are not significantly different across tree species and season respectively by Tukey's test. SD is the standard deviation. CV – coefficient of variation

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Table 2: Mean dry weight (kg) of leaf litter from the pruned branches of the dominant tree species in the banana agroforestry system in Uganda collected during different seasons for trees subjected to different pruning regimes

Tree species	Season/pruning regime		P value
	Dry	Wet	
Tree species			
Albizia coriaria	14.6±7.5 cA	17.8±5.1 dA	0.0614
Artocarpus heterophyllus	19.8±5.1bcA	22.3±5.5cA	0.2227
Ficus natalensis	25.6±7.2bA	28.8±4.1bA	0.1888
Mangifera indica	37.1±4.1aA	42.4±3.4aA	0.0734
CV	8.85	5.30	
F value	22.14***	47.39***	
	25%	50%	
Tree species			
Mangifera indica	39.9±4.1aB	45.7±2.1 aA	<0.0001
Ficus natalensis	22.3±1.4bB	32.1±2.6bA	<0.0001
Artocarpus heterophyllus	16.4±3.5cB	25.7±3.3cA	<0.0001
Albizia coriaria	12.8±2.2 dB	19.7±1.6dA	<0.0001
CV	5.12	2.71	
F value	77.71***	152.26***	
Pruning regimes	Dry	Wet	P value
25%	18.8±7.8bB	23.9±8.8bA	0.0381
50%	29.8±9.7aA	31.8±10.6aA	0.5415
P value	0.002	0.0093	

Same letters within a column (small letters) and row (capital letters) indicate means are not significantly different across tree species and season respectively by Tukey's test. CV – coefficient of variation

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Table 3: Nutrient concentrations in leaf litter collected from the dominant tree species in the banana agroforestry system in Uganda

Tree species	Nutrient concentration (%)					CV	F value
	Nitrogen	Phosphorous	Potassium	Calcium	Magnesium		
Albizia coriaria	2.2±0.0 cA	0.2±0.0 aE	1.3±0.0 aB	1.2±0.0 aC	0.8±0.0 aD	1.20	17795.1***
Artocarpus heterophyllus	3.7±0.0 aA	0.1±0.0 bE	1.1±0.0 bB	1.0±0.0 bC	0.2±0.0 dD	1.00	75063.2***
Ficus natalensis	2.4±0.0 bA	0.1±0.0 bD	1.0±0.0 cB	1.0±0.0 bB	0.6±0.0 bC	2.01	9055.23***
Mangifera indica	1.6±0.0 dA	0.1±0.0 bE	0.8±0.0 dC	1.0±0.0 bB	0.5±.0.0 cD	2.13	5649***
CV	0.74	9.98	1.49	2.04	2.26		
F value	11171.0***	30.00***	946.67***	194.48***	2220.0***		

Same letters within a column (small letters) and row (capital letters) indicate means are not significantly different across tree species and nutrients respectively by Tukey's test

REFERENCES

1. **Karamura EB, Turyagyenda FL, Tinzara W, Blomme G, Ssekiwoko F, Eden-Green S, Molina A and R Markham** *Xanthomonas* wilt of bananas in East and Central Africa. Diagnostic and Management Guide. Bioversity International, Uganda. INIBAP ISBN: 978-2-910810-85-2.2008.

2. **Bekunda MA** Farmers' responses to soil fertility in the banana–based cropping systems of Uganda. *Managing Africa' soils*1999; (**4**): 1–26.

3. **FAO.** Soil fertility management in support of food security in Sub –Saharan Africa. Food and Agriculture Organization. Rome, Italy, 2001.

4. **Tushemereirwe WK, Kashaija IN, Tinzara W, Nankinga C and N Steven** A guide to successful banana production in Uganda. Banana Production Manual, First edition. NARO, Kampala, 2001.

5. **Gold CS, Pena JE and EB Karamura** Biology and integrated pest management for the banana weevil *Cosmopolites sordidu*s (Germar) (Coleoptera: Curculionidea). *Integr. Pest Manag. Rev.* 2003; **6**:79–155.

6. **Nyombi K** Understanding growth of East Africa highland banana: Experiments and Simulation. PhD thesis, Wageningen University, the Netherlands. ISBN 978-90-8585-550-7. 2010.

7. **Smithson PC, McIntyre BD, Gold CS, Ssali H and IN Kashaija** Nitrogen and potassium fertilizer versus nematode and weevil effects on yield and foliar nutrient status of bananas in Uganda. *Nutr. Cycl. Agroecosyst.*2001; **59**: 239−250.

8. **UBOS.** The Population and Housing Census report. Uganda Bureau of Statistics**.** Entebbe, Uganda. 2002.

9. **Kyaddondo B** Uganda's population stabilization report. Population Secretariat. Kampala, Uganda. 2011.

10. **Kalyebara R** Socio-economics of banana production in Uganda. In: Assessing the Social and Economic Impact of Improved Banana Varieties in East Africa: Environment and production technology division (EPTD), International Food Policy Research Institute (IFPRI) workshop Summary Paper No. 15. Lusty C and S Melinda (eds) pp. 10−14. 2006.

11. **Sseguya H, Semana AR and MA Bekunda** Soil fertility management in the banana-based agriculture of central Uganda: farmers' constraints and opinions. *Afr. crop sci. J.*1999; **7**: 559−567.

12. **Baijukya FP, De Ridder N, Masuki KF and KE Giller** Dynamics of banana based farming systems in Bukoba district, Tanzania: Changes in land use, cropping and cattle keeping. *Agric. Ecosyst. Environ.* 2005; **106**: 395−406.

13. **Teklay T** Organic inputs from agroforestry trees on-farms for improving soil quality and crop productivity in Ethiopia. PhD thesis. Swedish University of Agricultural Sciences, Uppsala, Sweden, 2005.

14. **Muzoora AK** Farmer perceived soil fertility improving tree species, their litter and under canopy soil characteristics in livestock farms in Bushenyi district. MSc Thesis (Agroforestry), Makerere University, Kampala, Uganda, 2011.

15. **Pauli N, Barrios E, Conacher AJ and T Oberthur** Soil macrofauna in agricultural landscapes dominated by the Quesungual Slash-and-Mulch Agroforestry System, western Honduras. *Appl. Soil Ecol.* 2011; **47**:119−132.

16. **Siriri D, Ong CK, Wilson J, Boffa JM and CR Black** Tree species and pruning regime affect crop yield on bench terraces in South Western Uganda. *Agrofor. Syst.*2010; **78**:65–77.

17. **Chandrashekara UM** Effects of pruning on radial growth and biomass increment of trees growing in home gardens of Kerala, India. *Agrofor. Syst.* 2007**; 69**:231–237.

18. **Mukiibi JK, Esele JP, Oryot JOE, Twinamasiko E, Odongkara OK, Esegu JFO, Otim-Nape GW, Ssali H and W Odogola** Agriculture in Uganda. International Institute of Tropical Agriculture, 2001;**Vol3**:34 – 47.

19. **Burky J** Exploration of the potential of multipurpose trees and shrubs in agroforestry. In: Agroforestry a decade of development, Chapter 16 Research findings and proposals. World Agroforestry Center, ICRAF, Nairobi, Kenya, 2007.

20. **Karani PK** Management Plan for the Kikonda Forest Reserve, Kiboga District, Uganda. Available at http://www.piqqoprojects.com/projects/view/project/51.reviewed 2007. (Accessed on 05/03/2015), 1999.

21. **Kiboga District State of Environment Report** Kiboga District Local Council. Kiboga district, Central Uganda,2010.

22. **Nantale G, Kakudidi EK, Karamura DA, Karamura E and G Soka** Scientific basis for banana cultivar proportions on-farm in East Africa. *Afr. Crop Sci. J.* 2008;**16 (1):** 41 – 49.

23. **Mathers N, Fox NJ and A Hunn** Focus for Research and Development in Primary Health Care: How to Use Observations in a Research Project. Trent publishers.2002.

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24. **Okorio J** Final Report on Status of Forestry and Agroforestry in the Lower Kagera, Uganda. FAO Trans boundary Agro-ecosystem Management Programme (TAMP), 2006.

25. **Bedker PJ, O'Brien JG and MM Mielke** How to prune trees. USDA Forest Service. North-Eastern area state and private forestry. NA-FR-01-95, 1995.

26. **Whiting D, O'Connor A and E Hammond** Pruning maturing shade trees. Colorado State University Extension Colorado Master Garden program, Yard and Garden Publications 2013, CMG garden notes number 615. Colorado, USA, 2013.

27. **Abugre S, Oti-Boateng C and MF Yeboah** Litter fall and decomposition trend of *Hysiccurcas* leaves mulches under two environmental conditions. *Agric. Biol. J. North Amer.*2011; **2(3):** 462−470.

28. **Triadiati S, Tjitrosemito E, Guhardja S, Qayim T and C Leuschner** Litterfall production and leaf litter decomposition at natural forest and cocoa agroforestry in Central Sulawesi, Indonesia. *Asian J. Biol. Sci.* 2011; **4(3):**221–234.

29. **Gupta G, Yadav RS, Maurya D and SV Mishra** Litter dynamics under different pruning regimes of *Albiziaprocera*based agroforestry system in semi-arid region. *Asian Sci.* 2010;**5(2):** 93–97.

30. **Okalebo JR, Gathua KW and PL Woomer** Laboratory methods of soil and plant analysis: A working manual second edition. The Tropical Soil Biology and Fertility Program, Regional Office for Science and Technology for Africa UNESCO, Nairobi, Kenya, 2002.

31. **SAS Institute Inc.**SAS /STAT Users' Guide version 9.2, SAS Institute Inc., Cary, NC, USA, 2008.

32. **Sebukyu BV and MD Mosango** Adoption of Agroforestry Systems by Farmers in Masaka district of Uganda. *Ethnobot. Res. Applic.*2012; **10**:059–068.

33. **Isabirye EB** Role of agro-ecosystems in conservation of tree species in the Lake Victoria catchment: a case study of Baitambogwe sub-county, Mayuge district. M.Sc. Thesis, Makerere University, Kampala, 2009.

34. **Tabuti JRS** Important woody plant species, their management and conservation status in Balawoli Sub County, Uganda. *Ethnobot. Res. Applic.* 2012; **10**:269–286.

35. **Barlow J, Gardner AT, Ferreira VL, Carlos A and AC Peres** Litter fall and decomposition in primary, secondary and plantation forests in the Brazilian Amazon. *For. Ecol. Manag.*2007; **247**: 91−97.

36. **Zeng D, Mao R, Chang SC, Li L and D Yang** Carbon mineralization of tree leaf litter and crop residues from poplar-based agroforestry systems in Northeast China: A laboratory study. *Appl. Soil Ecol.* 2009; **44**:133 –137.

37. **Cayuela ML, Sinicco T and C Mondini** Mineralization dynamics and biochemical properties during initial decomposition of plant and animal residues in soil. *Appl. Soil Ecol.* 2009; **41**: 118–127.

38. **Andivia E, Vazquez JP, Fernandez M and R Alejano** Litter production in Holm oak trees subjected to different pruning intensities in Mediterranean dehesas. *Agrof. syst.* 2012; 87 (3): 657−666.

39. **Hansen RA** Effects of habitat complexity and composition on a diverse litter micro arthropod assemblage. *Ecol.*2000; **81**:1120−1132.

40. **Scherer-Lorenzo M, Bonilla LJ and C Potvin** Tree species richness affects litter production and decomposition rates in a tropical biodiversity experiment. *Oikos* 2007; **116**: 2108 – 2124.

41. **Ndakara OE** Litterfall and nutrient returns in isolated stands of *Persea gratissima* (avocado pear) in the rainforest zone of Southern Nigeria. *Ethiop. J. Environ. Stud. Manag.*2011; **4 (3):** 13−20.

42. **Chesney EKP** Shoot pruning and impact on functional equilibrium between shoots and roots in simultaneous agroforestry systems. *Agroforestry for biodiversity and ecosystem services – Science and practice*2012; **3:** 978–953.

43. **Tripathi OP, Pandey HN and RS Tripathi** Litter production, decomposition and hysic-chemical properties of soil in 3 developed agroforestry systems of Meghalaya, Northeast India. *Afr. J Plant Sci.*2009; **3 (8):**160–167.

44. **Hasanuzzaman MD and M Hossain** Nutrient Return through Leaf litter Decomposition of Common Cropland Agroforestry Tree Species of Bangladesh. *J. Biol. Sci.*2014; **3(8)**:82–88.

45. **Wood TW, Lawrence D and DA Clar** Determinants of leaf litter nutrient cycling in a tropical rain forest: soil fertility versus topography. *Ecosyst.*2006; **9**: 700–710.