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Leaf Decomposition and the Nutrients Release from Multipurpose Trees for Crop Production

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ABSTRACT

Decomposition and pattern of nutrients in the residual leaf material is important in assessing suitability of MPTs species to provide nutrients for growing crop. The rate of decomposition of organic matter, mineralization and release of nitrogen, phosphorus, potassium, calcium, magnesium of fresh leaf litter of five multipurpose trees (MPTs) were measured using litter bags for 12 weeks at the CSIR-Crops Research Institute's field at Kwadaso-Kumasi. Nitrogen concentration in leaf biomass sample of the MPTs ranged from 3.08 to 4.76% in the order *Albizia lebbeck* > *Leucaena leucocephala* > *Senna spectabilis* > *Gliricidia sepium* > *Senna siamea.* Potassium contents ranged from 0.43 to 0.68%. The decomposition process was slow in *S. siamea* and *A. lebbeck* which lost 45.2% and 43.3% respectively. Decomposition was highest in the 6th week, *S. spectabilis* and *L. leucocephala* losing 50.9% and 59.2% respectively. By the end of the 12th week *S. spectabilis*, *L. leucocephala* and *G. sepium* lost 75.8%, 75.9% and 79.1% respectively, representing 189.6g, 189.8g and 197.8g of leaves respectively. N release is considerably faster in the first six to eight weeks. On the basis of the results obtained from this study *Leucaena leucocephala* and *Gliricidia sepium* showed promise as materials that could be applied for the release of nutrient to growing crop especially nitrogen, phosphorus, potassium and calcium.

Keywords: Multipurpose Trees, Environmental Quality, Agroforestry and Decomposition

I. INTRODUCTION

The primary objective of any agroforestry system is the use of pruning from trees and shrubs as mulch, serving as sources of nutrients for crop production. In such systems, crop production depends on the recycling of nutrients within the system; recycling depends on the decomposition of organic material to form humus (organic matter) and the release of the nutrients contained in the humus [1]. Decreases in soil organic matter leads to a decline in agricultural productivity, poor environmental quality, soil degradation and nutrient depletion and food insecurity [2]. In order to halt the declining soil productivity resulting from organic matter depletion, a comprehensive knowledge of the organic material, decomposition and nutrient release patterns from leaf litter maximizes soil sustainability and crop productivity [3].

However, the decomposition of the litter from agroforestry system is a key process in the control of nutrient cycling and formation of soil organic matter [4] and the processes involved with litter decomposition is complex involving series of both physical and biochemical processes. Most often, the dynamics of litter production and decomposition are processes that replenish the soil nutrient pools, maintain soil health and thus ensure sustainability to agroforestry systems. [5]

A prerequisite for developing management strategies for green mulch is a clear understanding of the factors that govern the decomposition process [6] Nitrogen content [6], polyphenols content [7], polyphenol to N ratio [8], lignin plus polyphenol to N ratio [9]: [6] and C to N ratio and lignin to N ratio [10]: [6] of tree tissue used for green mulch have been associated with its decomposition and N release rates.

The selection and use of appropriate plant materials to maintain a sufficiently high nutrient supply to meet crop needs remains a major challenge of nutrient management under low input systems. With limited research methods and relatively expensive experimental cost, the study of litter decomposition has not reached such level as nutrient release dynamics until recently [11]. Although it seems clear from numerous field projects being undertaken in the tropics that application of leaf biomass is effective means of improving soil fertility, only a few reports have been produced from this study. Most of them do not contain convincing arguments about the decomposition of the litter and the pattern for the nutrient release. Indeed, leaf litter is a good source of nutrients for crop growth, but different leaf biomasses require different conditions and have different patterns for the release of its nutrient, whiles maximizing its decomposition rates for optimum availability for dependant crops.

A key issue is nutrient availability. Many research results suggest that leaf litters offer considerable potentials of improving soil productivity and increasing crop yield. A generalized reporting of the potential benefits and advantages are worth mentioning. However, the scenarios are different for every tree species. The availability of these nutrients through decomposition depends on several inherent and ecological factors.

The objectives of this experiment were to (1) determine the decomposition rate of leaf material from five multipurpose trees (2) study the fate of various nutrient elements in leaves during the decomposition process, and (3) determine the residual effect of the released of these nutrients. The study, therefore, focuses on the amount of nutrient in the leaf and the rate of decomposition of leaf from the five multipurpose trees.

II. METHODS AND MATERIAL

A. Study Site

The study was carried out during the major and minor season of 2014 at the research field at the Crops Research Institute, Kwadaso. The area has a bimodal rainfall pattern, the major season (April to July) with maximum rainfall in June and the minor season (September to November) with the maximum in October.

B. Litter Decomposition (Litterbag Technique)

Litterbag technique makes it possible to recover the residual experimental material even after the material has undergone some decomposition [12]. The experiment was carried out during the farming season to compare the rates of decomposition of the resource materials. Standard samples of 200g each of S. spectabilis, S. siamea, L. leucocephala, G. sepium and A lebbeck were placed in litter bags (50x50cm) made from mosquito nets (1.0mm mesh size) and buried in the soil at plough depth of 15cm in the same experimental plot for the same edaphic effect at the CSIR-Crops Research Institute's field at Kwadaso-Kumasi. Samples were recovered from the soil at an interval of 2, 4, 6, 8, 10, 12weeks (Anderson and Ingram, 1993).

C. Analysis for Resource Quality (Leaf Material)

Leaf samples harvested (fresh) were air-dried at room temperature to a constant weight. Sub-samples were then taken, milled and passed through a 2mm mesh sieve before they were analysed for various nutrients elements.

Total nitrogen of leaf resource material was determine using Kjeldahl's method involving oxidation by sulphuric acid and hydrogen peroxide with selenium as catalyst was used in the determination of total nitrogen.

Phosphorus content were determined after ashing 0.5 g leaf in a muffle furnace at a temperature of 450 – 500º C for 4 hours and then allowed to cool. The ashed sample was then removed from the oven, made wet with 1-2 drops of distilled water, and dissolved in a 10 ml 1:2 dilute HNO3 solution. The crucible was then heated on a hot plate until the first sign of boiling was observed. The crucible was removed and allowed to cool. The content was filtered into a 100 ml volumetric flask using a filter paper. The crucible was washed two times with about 20 ml distilled water. A 10 ml each of ammonium vanadate and ammonium molybdate solutions were added and shaken thoroughly. The solution was allowed to stand for 10 minutes for full colour development and then filled to the 100 ml mark. The absorbance of the sample and standard solutions was read on the spectrophotometer at a wavelength of 470mm and a standard curve was obtained by plotting the absorbance values of the standard solutions against their concentrations. Phosphorus concentration of the sample was determined from the standard curve.

Potassium in the ash was determined using the Gallenkamp flame analyzer. Potassium standard solutions were prepared with the following concentrations: 0, 10, 20, 40, 60, and 100 μg K per litre of solution. The emission values were read on the flame analyser. A standard curve was obtained by plotting emission value against their respective concentrations.

Calcium and magnesium were estimated using the procedure of [12]. A 25 ml aliquot of the ash solution was put in a conical flask. Potassium ferrocyanide solutions and potassium cyanide solutions were added to eliminate interfering cations such as Fe and Cu. The solution is titrated with 0.02 M EDTA solution using murexide as indicator. To determine calcium content, potassium hydroxide was added to raise the pH to about 12. At this pH, magnesium is precipitated leaving calcium in solution. The solution was titrated again with EDTA using Eroichrome Black T indicator. The difference in values between the first and second titres represents magnesium concentration in the solution.

D. **Statistical Analysis**

All the data collected were replicated and their means reported as represented in the results. Data collected were subjected to analysis of variance (ANOVA) using the software package Statistix 8 (Analytical software, 2003).

III. RESULTS AND DISCUSSION

A. Nutrient Composition of Litter

Nitrogen, phosphorus, potassium, calcium and magnesium concentration in the leaf litter did differ significantly among the species (table 1).The qualities of the leaf material were significantly different ($P \leq 0.05$) in their nutrient composition especially nitrogen and carbon. Nitrogen concentration in leaf material sampled from the MPTs ranged from 3.08 to 4.76% in the order Albizia lebbeck > Leucaena leucocephala > Senna spectabilis > Gliricidia sepium > Senna siamea (Table1). These multipurpose species has enormous nutrient potentials to supply the needed nutrients to the soil for plant growth.

The C/N ratios were below 25% (8.72-13.8), which indicates that there is net N-mineralization during decomposition. A relatively faster organic matter turnover is expected in the soil when biomass is applied as shown in Figure 2 and 3 where half-life of material was attained within 6 – 8weeks of decomposition of almost all five MPTs except A. lebbeck. P in leaf biomass was significantly different ($P \leq 0.05$) from 0.16 to 0.23% in the order Gliricidia > Senna siamea > Leucaena > Albizia > Senna spectabilis.

Potassium levels ranged from 0.43 to 0.68% in the order Leucaena leucocephala > Gliricidia sepium > Senna spectabilis > Senna siamea > Albizia lebbeck and were significantly different ($P < 0.05$). Calcium levels were ranged from 0.35 to 1.12% (Albizia lebbeck> Leucaena leucocephala> Senna spectabilis > Gliricidia sepium>Senna siamea). Carbon values were in the range 40.5-43.0% (Senna spectabilis > Senna siamea > Albizia lebbeck > Gliricidia sepium > Leucaena leucocephala). Amounts of Mg in leaf sampled were ranged from 0.39 to 0.59% (Albizia lebbeck > Leucaena leucocephala > Gliricidia sepium > Senna spectabilis > Senna siamea).

B. Litter Decomposition Pattern

The rate at which leaf of the five MPTs decomposed was in the order Gliricidia sepium > Leucaena leucocephala > Senna spectabilis > Senna siamea > Albizia lebbeck (Figure 1). Decomposition is expected to be fast using projections from the reported levels of N, as indicated by [13] that initial concentration of N in plant material is often the best predictor for N mineralization when contents of lignin and polyphenols are not high enough. Carbon: nitrogen ratio, is also a good predictor for N mineralization, the ranges reported are from 8.72 to 13.8 (Table 10). L. leucocephala and G. sepium showed a higher rate of decomposition, it is then expected that it would reflect in organic matter content or accumulation in the long run.

Decomposition was highest in the 6th week, S. spectabilis and L. leucocephala losing 50.9% and 59.2% respectively. By the end of the 12th week S. spectabilis, L. leucocephala and G. sepium have lost 75.8%, 75.9% and 79.1% respectively, representing 189.6g, 189.8g and 197.8g of mass of leaves respectively. The decomposition process was slow in S. siamea and A. lebbeck which lost 45.2% and 43.3% respectively. S. spectabilis and L. leucocephala attained half-life before the 6th week of decomposition whilst S. siamea and A. lebbeck may attain half-life after the twelve weeks of decomposition.

Decomposition showed a net N-mineralization which was highest at the 6th week, declining and assuming a moderate release to the end of the study period. The release of N in the 6th week indicates the suitability of the materials for most grain and legume production. Release pattern for P was high at 6th week compares with N but at lower amounts, generally K release peaked at 6th and 8th week.

For all the leaf materials, a significantly negative relationship existed between the percent of remaining dry matter and its nitrogen concentration. However, a significantly positive relationship existed between the percent of remaining dry matter and its potassium concentration.

C. Nutrient Release Patterns of Litter

Changes in nutrient concentrations of N, P, K, Ca, Mg, C and the quantities released in the mineralization of decomposed residual litter is shown in Figures 2 and 3 . It was generally observed that nutrient levels peaked at the 8th week before decreasing gradually as leaf litter decomposed and mineralized thus releasing nutrients into the surrounding soil. N release is considerably faster in the first six to eight weeks. There was no sign of net-immobilization of N and P as indicated in Figures 2-6.

A strongly negative relationship (R2= 0.90 - 0.93) of residual weight loss of decomposing leaf biomass and time in all the species.

The different rates of nutrient releases is in the order Albizia > Gliricidia >Leucaena > Senna siamea >Senna spectabilis. Even though L. leucocephala and Gliricidia showed high rate of decay and it was expected to have high built up of nutrients.

The N content from the MPTs is above the critical value of 2.00 – 2.50% [14]. However, the N content from the leguminous trees Albizia and Leucaena were significantly higher than those observed in the non-leguminous trees. This demonstrates the attribute of N-fixing of the leguminous trees.

These values are within the acceptable range 0.17% and 0.20% though there may be extremes of 0.30%. P levels of the leaf from the MPTs are low to moderate (0.16 – 0.23%). Palm et al (2001) demonstrated that legumes have comparatively lower P and net-immobilization is expected when biomass is applied to the soil. Potassium levels in the range of 0.43-0.68% is considered low to moderate, compared with expected values of 1.0 – 2.5% K, 2.5 – 4.0%N, 0.1 – 0.3%P and1.5 – 2.0% Ca as indicated by Budelman, (1989).

Concentration of N and P in fresh plant litter, measured at the onset of the decomposition study, varied significantly among the different litter (Table 1). Linear regression analysis indicated that initial tissue N and P concentration increased significantly (P<0.05) with decreasing litter mass. This trend apparently was due to the nutrient gradient downstream from the inflow, and its inherent initial nutrient levels between the biomasses which accounted for the significant difference in tissue N and P between the biomasses.

Decomposition is recognized as important because plant production depends on the recycling of nutrients within the system; recycling depends on the decomposition of organic material to humus and release of the nutrient it contains. Tian et al., (1998), recognized soil fauna in his report as palpable factor which affects decomposition mainly through the combination of substrates, and influencing microbial activity. The pronounced difference in decomposition rates reported here may be the result, in part, of the significant contribution of the soil fauna and environmental factors. Adejuyigbe (2000) and Cox et al. (2001) attributed litter decomposition and release of N, P, K, Ca and Mg to the influence of micro arthropods and earthworms.

Initial lignin and N content of the organic substrate (e.g. plant tissue) have been correlated with decomposition rate (Aber et al. 1990). However, there is evidence that, during later stages of decomposition, the chemical quality of substrates of different initial compositions is reduced to a 'least common denominator', so that variability in decay rate is a function of environmental factors alone (Melillo et al. 1989). Comparing the initial and final nutrient concentrations in the decomposing biomass showed that N and P mineralization had occurred in the substrate during the incubation period (Figures 2 and 3). Generally, N and P mineralisation is dependent on the initial N concentration in the biomass. N mineralization was more pronounce at the half-life of the residue for the leguminous tree species. Our study results suggest that the rate of decomposition of the plant residue were influenced largely by litter quality.

The highest decomposition trend obtained for Leucaena leucocephala and Gliricidia sepium is probably caused by the relatively low C/N value (Table 1). This says that organic materials with a low C to N ratio will decompose faster than a material with a high C:N ratio. This theory states that nitrogen is normally the limiting factor for many of the organism populations. With a higher amount of nitrogen (a low C: N ratio) these populations are more free to grow rapidly and to higher concentrations, because of the nutrient cycling through the decomposing leaves (Knops, 2003).

Increased mass loss during the first 2 weeks of decomposition could be the result of microbial utilization of highly labile compounds of the substrate, such as non-structural carbohydrates. When these are depleted the rate of mass loss is also decreased (McClaugherty and Berg, 1987). Labile fraction of litter is rapidly metabolized by micro-organism or lost through leaching. Parson et al. (1990) rather explained that although some of the labile material may be water soluble, micro-organism metabolism rather than leaching is responsible for the greatest part of mass loss. Hunt et al. (1988) in a report explained differences in decomposition pattern and rates among substrate as related to the amount of labile or rapid decomposing fractions (sugars, starches, proteins) and the recalcitrant or slowly decomposing fraction (cellulose, lignin, fats, tannins and waxes).

Nitrogen, phosphorus and potassium concentrations showed a similar pattern and their concentrations increased over time for all litters. At the end of the experiment, nitrogen release for Albizia lebbeck was higher than Senna siamia and was significantly greater than Senna siamea where magnesium levels were similar to initial values. Nitrogen and phosphorus content in decaying leaves fluctuated over time between mineralization and release, with a trend towards net retention in relation to dry matter, depending on the litter type. Nitrogen and phosphorus net release during the first 2 weeks occurred only in Albizia, Gliricidia and Leucaena, but more evidently with Albizia.

Litter decay is a complex process with marked differences among nutrients in their rates of release. The release of nutrient from the decomposing litter is known to be influenced by several factors. According to O'Connell and Grove (1996), Potassium, magnesium and calcium are among the most mobile nutrients in litter. The release of nutrients that are not limiting microbial decomposers, and are not structurally bound in litter, may exceed mass loss, and leaching of leaf litter is commonly associated with the fast initial release of potassium (O' Connell and Grove 1996). The high decomposition and nutrient release of Albizia and Leucaena in this study is in agreement with earlier studies by Vanlauwe et al., (1997) who reported that species with high nitrogen content decompose more rapidly than species low in nitrogen.

The result indicated higher rate of N, P, K and Na release for Albizia, Gliricidia and Leucaena. Similar trend has been observed by Singh (1980) and Adejuyigbe (2000) in the humid tropical forest. This rapid release could be attributed to the rapid loss of water soluble compounds. The pattern of nutrient release observed in this study could be taken advantage to synchronize the nutrient release with crop production.

TABLE 1: INITIAL NUTRIENT COMPOSITION OF LEAF BIOMASS

Nutrient source/ Treatment	% P	% K	% N	% Ca	% Mg	% Carbon	% Organic Matter	C:N ratio	% Lignin	% Polyphenols
Senna	0.16	0.57	3.88	0.35	0.41	43.0	86.0	11.08	15.50*	1.7*
spectabilis										
	0.18	0.47	3.08	0.54	0.39	42.5	85.0	13.80	17.3	7.2
Senna siamea	0.18	0.68	4.48	0.90	0.59	40.5	81.0	9.04	16.66*	1.60*
Leucaena										
leucocephala	0.23	0.66	3.55	1.12	0.57	40.5	81.0	11.41	16.61*	1.60*
Gliricidia										
sepium	0.18	0.43	4.76	0.42	0.63	41.5	83.0	8.72		
Albizia									-	-
lebbeck	0.021	0.008	0.021	0.031	0.021	0.3261	2.306	0.0912		
Lsd (0.05)	*0.19*	*0.56*	*3.95*	*0.66*	*0.52*	*41.6*	*83.2*	*10.81*		
Overall mean	5.89	0.80	0.21	2.47	2.11	0.2410	0.2410	17.60		
CV (%)										

Means in the same column followed by the same letter are not significantly different from each other at (P≤0.05)
* Values adapted from Palm et al, (2001). High lignin and low soluble polyphenols

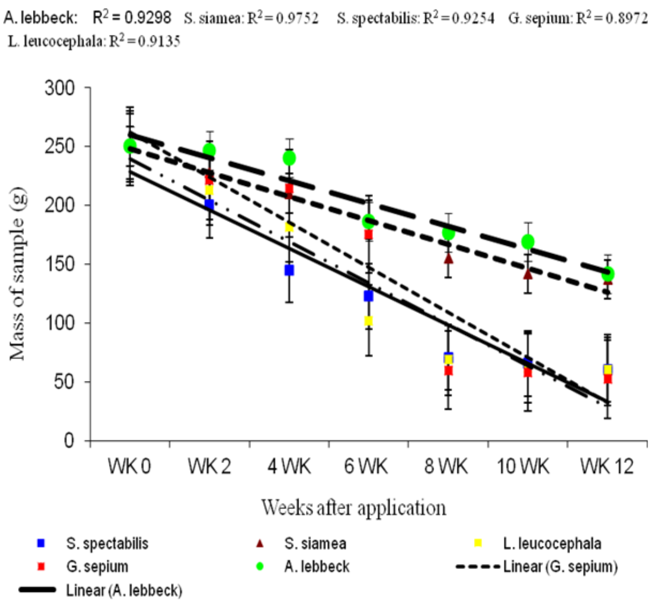
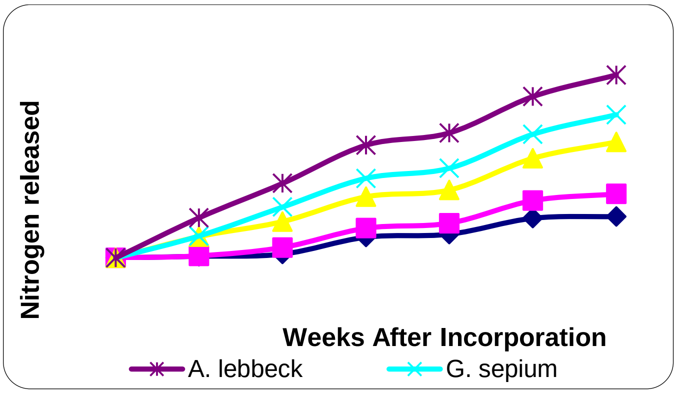
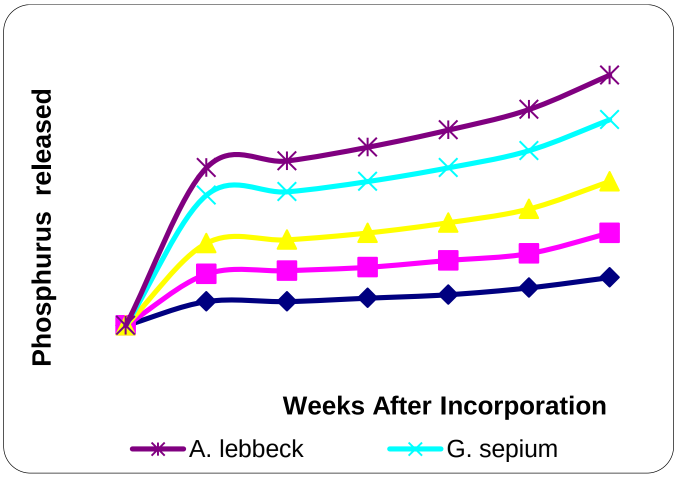


Figure 1: Relationship between residual weight losses of decomposing leaf of MPTs with time.





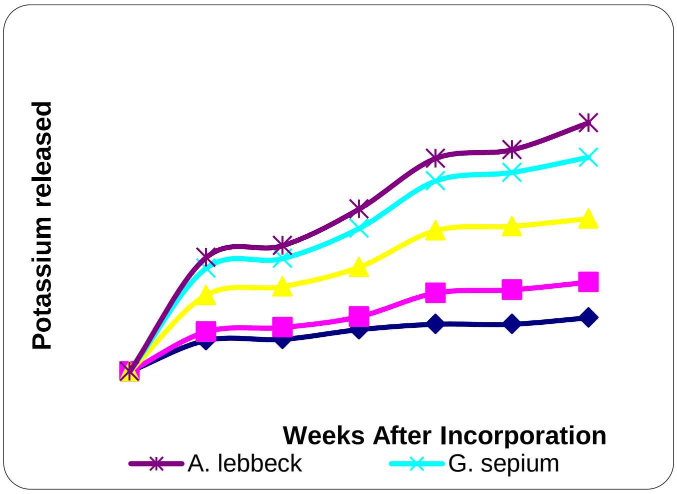
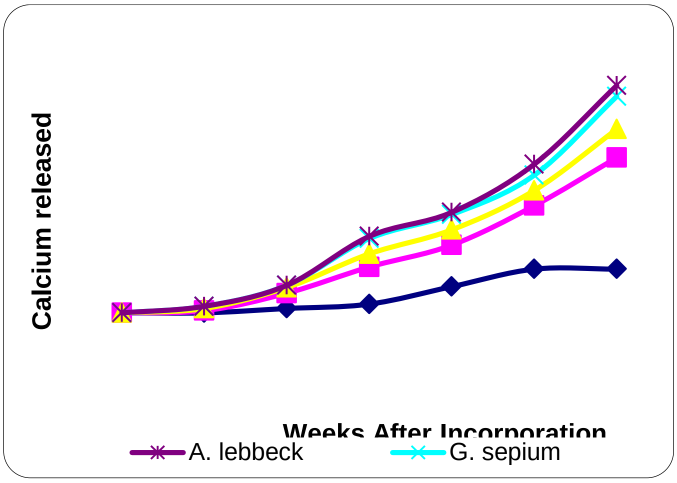


Figure 2 : Nutrient Release in decomposing biomass



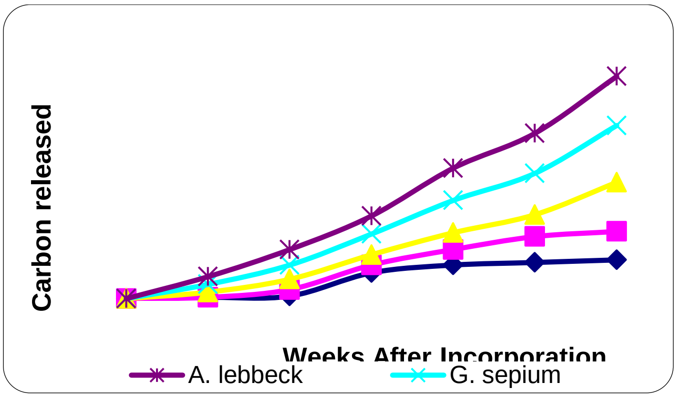


Figure 3 : Nutrient Release in decomposing biomass

IV. CONCLUSION

There were significant differences in the levels of the nutrient elements N, P, K, Ca, Mg and C/N, the rates of decomposition and levels of residual nutrient after fortnightly recovery. The pattern of decomposition and nutrient release from the leaves of the MPTs shows the potential to provide nutrient on sustainable basis from organic materials for growing crops. The levels of nutrient in the leaves provided for by the five MPTs species are within sufficiency ranges especially for N. Their decomposition and residual nutrient showed nutrient released to be fairly fast. Albizia lebbeck and Senna siamea were moderate to slow compared to the fast decomposing Leucaena leucocephala, Gliricidia sepium and Senna spectabilis.

It is important to consider the intrinsic capacities of the species to release and provide major soil nutrient in appreciable quantities timely for efficient use by crop when we recommend the application of leaf material from these MPTs. Leucaena leucocephala, Gliricidia sepium and Senna spectabilis has the potential to improve soil and provide leaves that are rich in soil nutrients to support crop production. Effort should be made to study avenues of improving P in soil this include inoculation of MPTs seedling with mycorhizae and application of rock phosphates which abounds in the country.

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