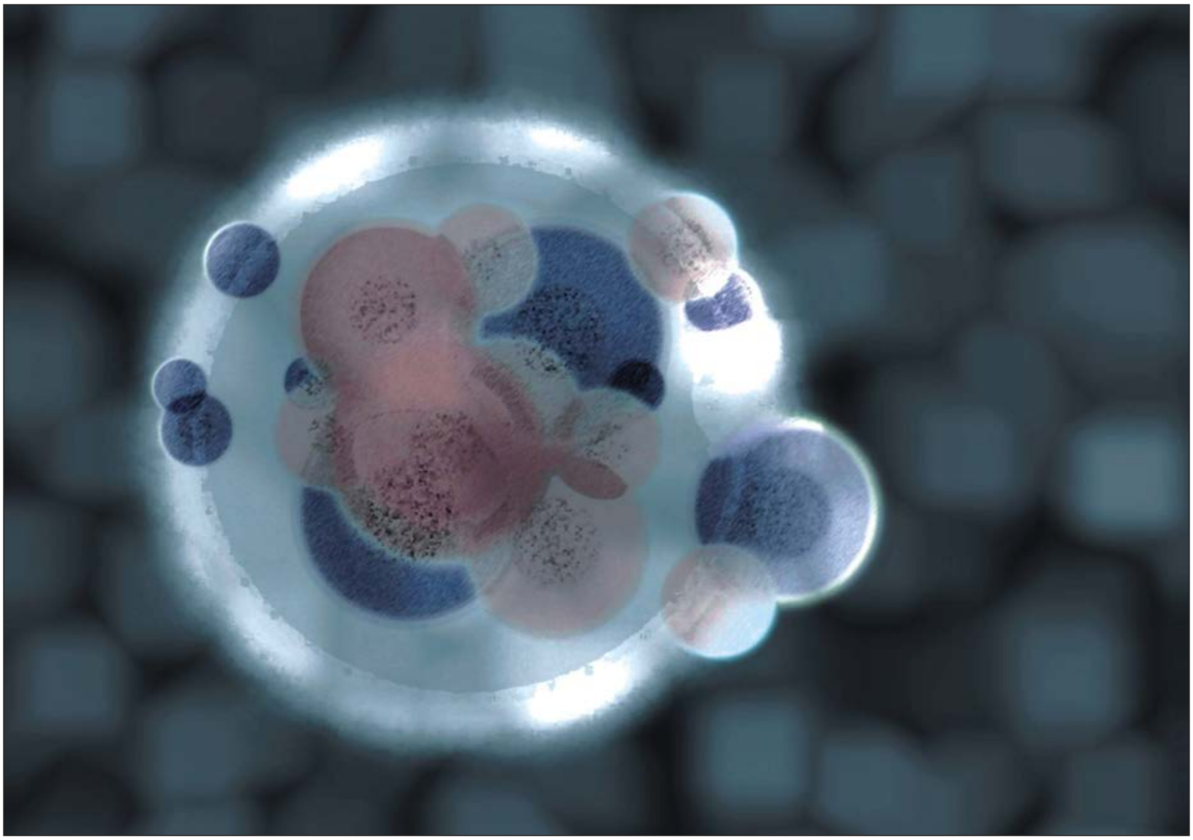

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Nitrogen Storage and N-Use Efficiency of Maize as Influenced By Litter Quality and Placement Methods

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Abstract: Nitrogen storage and N-use efficiency as influenced by litter quality and placement method was in investigated in nutrient deficient soil in Akure. Mixed fresh pruning of *Gliricidia sepium* (high quality) and *Acacia auriculiformis* (low quality) were mixed at varying proportion of 100:0 (*Gliricidia: Acacia* proportion); 80:20; 60:40; 40:60; 20:80; 0:100 and 0:0 (control) to simulate litter of varying quality. The mixed litter were mulched (above ground) or incorporated (below ground) around maize planted at an escapement of 90 × 30 cm (between and within rows). Maize plants were harvested at 4 weeks after planting (4 WAP); 6 WAP and 8 WAP and analysed for dry matter, N storage and N-use efficiency in the root, stem and the leaf. N storage by maize was improved with the application of various proportions of leaf residues and was significantly ($p<0.005$) higher than that in the control treatment. At the early stage of growth (4 WAP), maize plants mulched with 60:40 (*Gliricidia: Acacia*) leaf mixture showed the highest N storage for the root (0.170 g/plant). In the stem maize plants mulched with 100.0 and 0:100 proportions has a significantly ($p<0.005$) higher N storage which were 0.130 g/plant and 0.128 g/plant respectively. In the leaf, 80:20 and 0:100 mulch proportions had significant higher N storage. This similar trend was observed for N storage for maize in the root, stem and the leaf at 6 WAP. However, at maize maturity (8 WAP) which coincide with the grain production growth phase, the N storage as influenced by different litter quality was not significant in the root stem and leaf. At the early stage of growth (4 WAP), the N - use efficiency in the root, stem and the leaf improved with increased proportion of *Gliricidia* component when applied as mulch. However at later stages of growth (6 and 8 WAP), the N-use efficiency improved only with increased proportion of *Acacia* in the *Gliricidia*: *Acacia* leaf mixture.

Key words: Decomposition, mineralization mulch, synchrony, organic matter, plant demand

INTRODUCTION

Both economic and environmental concern have led to renewed interests in legume residue as a source of N in agricultural systems. In order to optimize the use of legume N for subsequent or companion crop, it is necessary to be able to estimate accurately their mineralization rate after being incorporated into the soil (Giller and Cadish, 1995).

The mineralization of a specific type of plant residue, given favourable environmental conditions, has been shown to be largely determined by a variety of chemical and physical plant quality parameters (Heal *et al*., 1997). Several plant quality parameters and indices have been proposed for predicting decomposition and nitrogen release patterns. They include nutrient quality (Total nitrogen, total phosphorus, total carbon), carbon quality (lignin, soluble carbon, soluble polyphenol) and physical quality (toughness, waxiness or stiffness) (Palm and Rowland, 1997). Under field conditions, the contributions of litter N to crop nutrition is often small and crop N recoveries from litter prunings are often less then 20% (Giller and Cardisch, 1995). The poor efficiency of nitrogen use from high quality litter from tree legume such as *Gliricidia sepium* is often attributed to lack of synchrony between crop N demand and N release couple with losses of N due to leaching (Myers *et al*., 1997).

There is therefore a need for strategic research to examine the potentials for achieving synchrony through manipulation of litter quality and placement methods. The primary aim for manipulating plant quality is to improve synchrony between N release from high quality litter and crop N demand in order to improve N use efficiency to avoid nutrient losses under high rainfall conditions.

MATERIALS AND METHODS

Procedure for field experiment: The experiment was carried out on a nutrient deficient soil where preliminary uniformity growth trial using maize (*Zea mays* L) has shown symptom of N deficiency. Three plots measuring 12×6 m each were demarcated and cleared of initial vegetation. Each demarcated and cleared land area was divided into eight equal 3×3 m plots. Maize seeds (*Zea mays* L.) were sown at an escapement of 90×30 cm (between and within rows) at the beginning of the rainy season. Fourteen days after sowing, the maize plants were mulched (above ground placement) and incorporated (below ground placement) with mixed fresh leaf pruning of *Gliricidia sepium* (high quality litter) and *Acacia auriculiformis* (low quality litter) in different proportions of *Gliricidia* and *Acacia* to constitute the experimental treatments. The treatments comprise of:

100:0 (*Gliricidia: Acacia* Proportion)
80: 20
60.40
40.60
20.80
0:100
0.0 (No application)

The fresh mixed leaves were applied at the rate of 3.0 t ha^{-1} (83 g/plant) for *Gliricidia sepium* and 3.8t ha^{-1} (103 g/plant) for *Acacia auriculiformis*. The nitrogen content in the fresh leaf sample of each species was used as basis for determining the quantity of fresh leaf prunings to be added and incorporated into the planted maize to supply equivalent amount of 70 kg N ha^{-1}, a standard N fertilizer requirement for maize in the South Western Nigeria (Enwezor *et al*., 1989).

The experiment was laid in a Completely Randomized Design (CRD) at three replicates. At two weeks interval during maize growth, three replicates per treatment of maize plant were uprooted and separated into leaf, stem and root. The fresh weights of each plant constituent parts (root, stem and leaf), weighing 50 g for each treatment plot were oven dried at 100°C for 48 h to constant weight to determine dry matter content. The dry matter for the sub-samples was used to compute dry matter yield of the plot samples as:

$$\text{Total dry wt (g)} = \text{sub-sample dry wt (g)} \times \frac{\text{Total fresh wt (g)}}{\text{sub-sample fresh wt (g)}}$$

Determination of N storage and N-use efficiency

At each sampling time, sub-samples of maize constituent parts were dried at 65°C and weighed for dry mater. The oven dried samples were ground to pass through 20 mesh sieve for N analysis. Total N was analyzed by micro-kjedahl digestion, followed by distillation and titration (AOAC, 1990).

Nutrient storage was calculated as:

$$\text{N storage} = \text{Dry matter (g)} \times \text{N concentration (g/plant)}$$

While

N-Use efficiency was determined as:

$$\text{N-Use efficiency} = \frac{\text{Dry matter}}{\text{N uptake}} \text{(g dm/g N storage)}$$

(Moll *et al*., 1982).

Statistical analysis: The data on the influence of litter quality and placement method on N-use efficiency of maize were subjected to factorial analysis of variance using SAS statistical package (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

The effect of manipulated litter quality on N storage by maize plant parts (root, stem, leaf) during different periods of growth which include 4 WAP (weeks after planting), 6 and 8 WAP are shown in Table 1-3, respectively. At the early stage of growth (4 WAP) maize plants mulched with 60:40 (*Gliricidia Acacia*) leaf mixture showed the highest N storage for the root (0.170 g/plant) while the plants mulched with 100:0, 80.20; 40. 60 and 0.100 were significantly higher than the control (0.012 g/plant). For the stem, maize plants mulched with 100:0 and 0:100 proportions has a significantly higher N storage which were 0.130 and 0.128 g/plant, respectively than 80:20, 60.40, 40.60 and 20. 80 proportions. The control plot recorded the lowest N storage of 0.028 g/plant (Table 1).

In the leaf, the 80:20 and 0:100 mulch proportions has a significantly higher N storage, which were 0.207 and 0.205 g/plant than those of 100.0, 60:40, 40:60 and 20:80 *Gliricidia: Acacia* proportions.

At 6 WAP, significantly higher ($p<0.05$) N storage in the root were obtained for 100:0 and 80:20 mulch proportions which were 0.123 and 0.148 g/plant. The N storage for 40:60, 20:80 and 0:100 mulch proportions were not significantly different, while the control plot also recorded the significantly lowest N storage (0.021 g/plant. Similar trend was also observed in the stem and leaf parts (Table 2).

However, at maturity (8 WAP), which coincide with the grain production growth phase, the N storage as influenced by different litter quality was not significant in the root, stem and leaf ($p>0.05$) and were not different from the control treatment (Table 3).

Effect of N-use efficiency as influenced by quality of litter and placement method: The effect of different litter qualities mulched (above ground placement method) on

Table 1: Effect of litter quality on N storage in maize plant parts at 4 WAP (weeks after planting)

Litter quality *Gliricidia/Acacia* proportion	N storage (g/plant) Root	Stem	Leaf
100:0	0.034^{ab}	0.130^{bc}	0.159^{ab}
80:20	0.031^{ab}	0.098^{a-c}	0.207^{b}
60:40	0.170^{a}	0.063^{ab}	0.130^{ab}
40:60	0.032^{ab}	0.102^{a-c}	0.190^{ab}
20:80	0.041^{b}	0.114^{a-c}	0.160^{ab}
0:100	0.027^{ab}	0.128^{bc}	0.205^{b}
0:0 (controls)	0.012^{c}	0.028^{a}	0.050^{a}

Means with dissimilar superscript(s) in the same column differ ($p<0.05$) significantly

Table 2: Effect of litter quality on N storage in maize plant parts at 6 WAP

Litter quality *Gliricidia/Acacia* proportion	N storage (g/plant) Root	Stem	Leaf
100:0	0.123^{b}	0.259^{bc}	0.473^{b}
80:20	0.148^{b}	0.381^{dc}	0.783^{c}
60:40	0.039^{a}	0.151^{ab}	0.215^{a}
40:60	0.089^{ab}	0.210^{bc}	0.349^{ab}
20:80	0.108^{ab}	0.291^{cd}	0.297^{ab}
0:100	0.099^{ab}	0.489^{c}	0.543^{b}
0:0 (controls)	0.021^{a}	0.023^{a}	0.132^{a}

Means with dissimilar superscript(s) in the same column differ ($p<0.05$) significantly

Table 3: Effect of litter quality on N storage in maize plant parts at 8 WAP

Litter quality *Gliricidia/Acacia* proportion	N storage (g/plant) Root	Stem	Leaf
100:0	0.161^{a}	0.789^{a}	0.760^{a}
80:20	0.153^{a}	0.519^{a}	0.557^{a}
60:40	0.134^{a}	0.748^{a}	0.620^{a}
40:60	0.111^{a}	0.583^{a}	0.461^{a}
20:80	0.102^{a}	0.623^{a}	0.527^{a}
0:100	0.118^{a}	0.728^{a}	0.582^{a}
0:0(controls)	0.060^{a}	0.407^{a}	0.544^{a}.

Means with dissimilar superscript(s) in the same column differ ($p<0.05$) significantly

maize N-use efficiency at 4, 6 and 8 WAP are shown in Fig. 1-3 while that of belowground placement are presented in Fig. 4-6, respectively. The N-use efficiency generally was higher in the root than in the stem and lowest in the leaf. At the early stage of growth (4 WAP), the N-use efficiency in the root and stem increased with increasing proportion of *Gliricidia* component in the *Gliricidia/Acacia* leaf mixture when applied as mulch. However, at later stages of growth (6 and 8 WAP), the N-use efficiency increased with increasing proportion of Acacia in the *Gliricidia /Acacia* leaf mixture.

When the leaf mixture was incorporated (below ground placement) around maize plants, the N-use efficiency in the root, stem and leaf improved with increase proportion of *Acacia* component in the *Gliricidia/Acacia* leaf mixture even at the early stage (4 WAP) of growth. When pure *Gliricidia* was applied either above ground or below ground the N-use efficiency both in the root and stem appeared generally lower than when pure *Acacia* was applied.

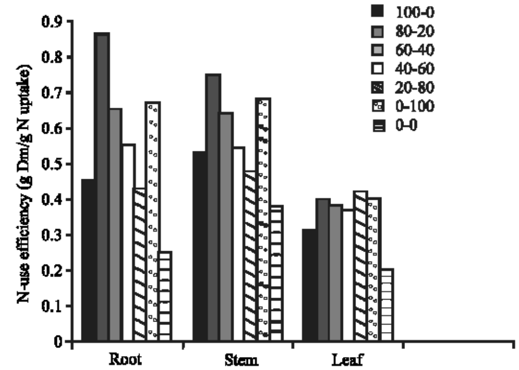

Fig. 1: Effect of litter quality on N-use efficiency of maize mulched (above ground placement) with mixed *Gliricidia: Acacia* (100:0; 80:20; 60:40; 40:60; 20:80; 0:100; 0:0) leaves at 4 WAP

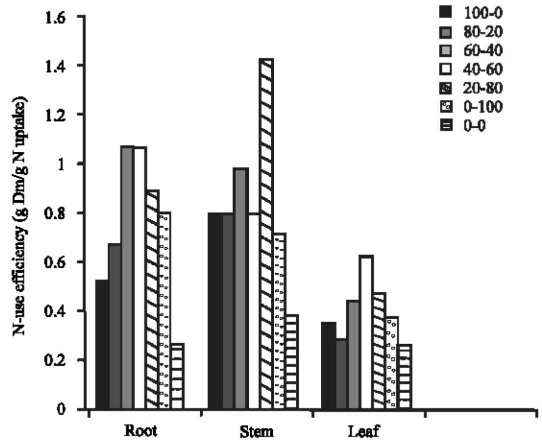

Fig.2: Effect of litter quality on N-use efficiency of maize mulched (above ground placement) with mixed *Gliricidia: Acacia* (100:0; 80:20; 60:40; 40:60; 20:80; 0:100; 0:0) leaves at 6 WAP

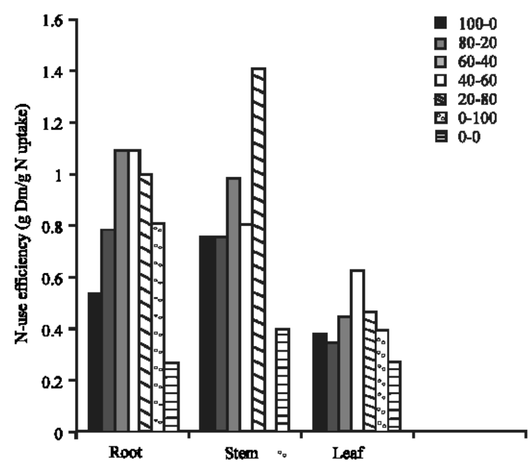

Fig.3: Effect of litter quality on N-use efficiency of maize mulched (above ground placement) with mixed *Gliricidia: Acacia* (100:0; 80:20; 60:40; 40:60; 20:80; 0:100; 0:0) leaves at 8 WAP

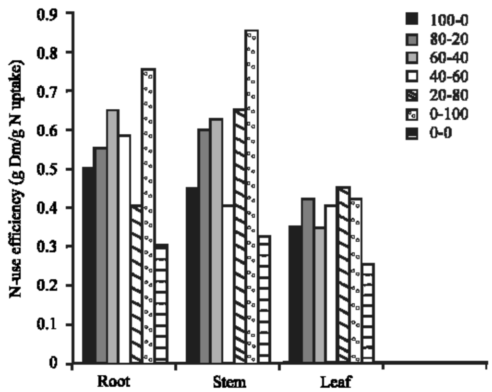

Fig.4: Effect of litter quality on N-use efficiency of maize incorporated (below ground placement) with mixed *Gliricidia: Acacia* (100:0; 80:20; 60:40; 40:60; 20:80; 0:100; 0:0) leaves at 4 WAP

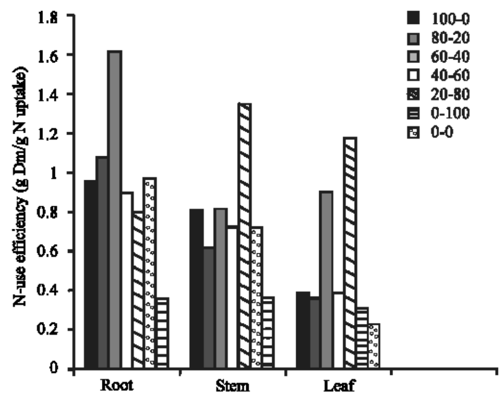

Fig.5: Effect of litter quality on N-use efficiency of maize incorporated (below ground placement) with mixed *Gliricidia: Acacia* (100:0; 80:20; 60:40; 40:60; 20:80; 0:100; 0:0) leaves at 6 WAP

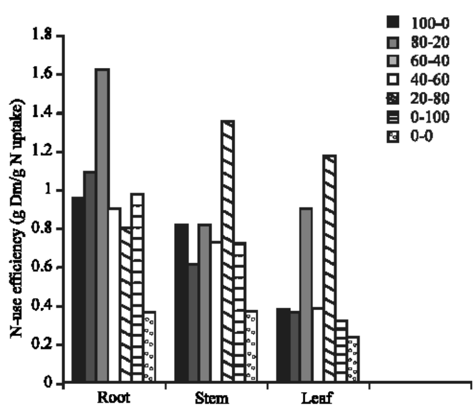

Fig.6: Effect of litter quality on N-use efficiency of maize incorporated (below ground placement) with mixed *Gliricidia: Acacia* (100:0; 80:20; 60:40; 40:60; 20:80; 0:100; 0:0) leaves at 8 WAP

N storage by maize crop was improved with application of leaf mixture with varying litter quality. The values for N storage were generally higher than that in the control treatment. It is well established (Haggar *et al*., 1993) that labile pools of organic bound nutrient in the soil can be augmented by increasing the input of high quality organic material. Thus the high N concentration in maize plants with leaf residue treatment as compared with the control suggests that the increase in concentration was due, at least, in part, to higher N availability.

Placement method (above ground or below ground) of mixed leaf residue of varying quality had no significant effect on N storage by maize. This finding agrees with earlier report (Jama and Nair, 1996) that placement on or below the soil surface of mulch, has no significant effect on decomposition, although the authors reported a higher rate of initial decomposition of low-quality litter such as cassia leaves placed belowground than surface placed leaves.

The higher N storage of the residue treatment plots compared to control plot was already established at 28 days (4 WAP) and the subsequent N storage at later stage of growth (6 WAP) largely built on that difference. Although maize plots treated with residue mixture that has large proportion of *Gliricidia* had initial higher relative N. storage than those with large proportion of *Acacia;* however at later stage (6 WAP) N storage were not significantly different between plots treated with residue mixtures. At the early stage of growth (4 WAP) and before grain production (6 WAP), crop N storage did not reflect differences in the proportion of *Gliricidia* or *Acacia* in the *Gliricidia/Acacia* mixture (Table 1 and 2). Low direct N contribution is expected from *Acacia* litter due to slow decomposition and N release (Tian *et al*., 1992). This did not however explain the improvement in N storage with increase proportion of *Acacia* mulch in the *Gliricidia/Acacia* leaf mixture.

At plant maturity (8 WAP), the amount of N storage as influenced by litter quality was not significant and are not different from the control treatment (Table 3). The timing of the transfer of mulch N to the crop appeared to be mainly during the early growth phase. This findings corroborate the earlier findings in this respect by Haggar *et al*. (1993). The higher proportional contribution of mulch N to crop N relative to control in the first 6 weeks and the similar N storage at 8 WAP for the varying litter quality treatments, suggest that a flush of available N was released from mulch during the first 6 weeks after sowing.

Plant residues poor in N, but with large concentrations of lignin and polyphenols decompose and release N slowly, so that little of the plant N applied is available for the succeeding crop although it remains in the soil. Conversely, residues rich in N but with small amount of lignin and polyphenol concentrations decompose rapidly and supply large amount of N during the early periods of growth, but may not contribute much to the maintenance of soil organic matter (Giller and Cardisch, 1995). The efficiency of N-use in this study appeared generally low for maize crops mulched with pure *Gliricidia* (high quality litter) than those mulched with mixed *Gliricidia/Acadia* leaf residue. Also, the N-use efficiency improved with increased proportion of Acacia in the *Gliricidia/Acacia* mixture (Fig. 1-3). The poor efficiency of N use from high quality litter from trees such as *Gliricidia sepium* can be attributed to lack of synchrony between crop N demand and N release coupled with losses of N due to leaching as earlier indicated by Myers *et al*. (1997). Although residues high in lignin and polyphenol contents (low quality residue) exhibit delayed N release, but will after a while release nutrient rapidly. This probably explains the improved N-use efficiency with increased *Acacia* proportion in the mixture with time as observed in this study.

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REFERENCES

A.O.A.C., 1990. Association of Official Analytical Chemist. Official Methods of Analysis. 15th Edn., Washington DC., USA.

Enwezor, W.O., J.E. Udo, K.A. Ayotade, J.A. Awopetu, V.O. Chude and C.I. Udegbe, 1989. Fertilizer use and management practices for crops in Nigeria (Series No. 2) FPDD, pp: 163.

Giller, K.E. and G. Cardisch, 1995. Future benefits from biological nitrogen fixation an ecological approach to agriculture. Plant and Soil, 174: 255-277.

Haggar, J.P., E. Tanner, V.J. Beer and D.C.L. Kass, 1993. Nitrogen dynamics of tropical agroforestry and annual cropping systems. Soil Biol . Biochem., 25: 1363-1378.

Heal, O.W. J.M. Anderson and M.J. Swift, 1997. Plant Litter Quality and Decomposition. An Historic Overview. In Cadish, G. and K.E. Giller (Eds). Driven by Nature: Plant Litter Quality and Decomposition . CAB International, Wallingford, UK., pp: 3-30

Jama, B.A. and R.K.R. Nair, 1996. Decomposition and Nitrogen mineralization patterns of *Leucaenale cocephala* and *Cassia siamea* mulch under tropical seminarial conditions in Kenya. Plant and Soil, 175: 275-285.

Moll, R.H., E.J.K. Kamprath and W.A Jackson, 1982. Anlysis and interpretation of factors which contribute to efficiency of nitrogen utilization. Agron. J., 74: 562-564.

Myers, R.J.K., M. Van Noordwijk and Patma Vityakon, 1997. Synehrony of Nutrient Release and Plant Demand. In Cadisch, G. and K.E. Giller (Eds). Plant Litter Quality Soil Environment and Farmer Management Options. Driven by Nature: Plant Litter Quality and Composition. CAB International, Wallingford, UK., pp: 215-229.

Palm, C.A. and A.P. Rowland, 1997. A Minimum Dataset for Characterization of Plant Quality for Decomposition. In Cadisch, G. and K.E. Giller (Eds.). Driven by Nature: Plant Litter Quality and Decomposition: CAB International, Wallingford, UK., pp: 379-392.

Steel, R.G.D. and J.H. Torrie, 1980. Principle and Procedures of Statistics. McGraw Hill Book Coy, Inc. New York, USA.

Tian, G., B.T. Kangs and L. Brussaard, 1992. Biological effects of plants residues with contrasting chemical compositions under humid tropical conditions. Decomposition and nutrient release. Soil Biol. Biochem., 24: 1051-1060.