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Full Length Research Paper

Mineralization and N-use efficiency of tree legume prunings from fertilizer tree systems and low quality crop residues in Malawi

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There is substantial evidence that fertilizer tree systems are capable of maintaining increased and sustainable crop production on low fertility soils in southern Africa, thus reducing the required amount of chemical fertilizer. However, crop yield increase in soils amended by fertilizer tree systems can only be optimized if nutrient release by the organic materials and nutrient demand by the crop are in synchrony. The decomposition and N release patterns of high quality tree prunings (gliricidia and sesbania) and crop residues (pigeon pea leaves and roots, and maize stover) were studied to understand the N use efficiency of fertilizer tree systems. The treatment were (1) quality pruning residues from gliricidia (Gs) and sesbania (Ss), (2) three medium quality residue levels including pigeon pea leaves (Pea-L), pigeon pea leaves + roots (Pea-LR) and pigeon pea roots (Pea-R), and (3) two rates of maize stover (Stover-1 and Stover-2) as low quality residues, and control (no crop residues, no tree prunings). The treatment combinations were laid out as a randomized complete blocks design. Mixtures of tree prunings with 2.5 t ha^{-1} maize stover increased maize N uptake and grain yield whereas 5 t ha^{-1} maize stover reduced maize N uptake and grain yield during the wetter season. Mixtures of Pea-R, Stover-1 or Stover-2 with tree prunings depressed yields during the drier season. Stover-2 had the highest N fraction immobilized N, respectively 15 and 35% N during the wetter and drier conditions. We conclude that (1) mixing of high quality tree prunings with crop residues may enhance the decomposition of low quality crop residues but there is no special interaction, and (2) remineralization of N immobilized early in the season by the low quality organic materials is stimulated by well distributed rainfall.

Key words: Legumes, maize stover, N uptake, immobilization, remineralization.

INTRODUCTION

The use of green manure from nitrogen fixing tree/shrub prunings has been promoted as an alternative source of nitrogen (N) for smallholder farmers in sub-Saharan countries. Although addition of such tree prunings has been shown to increase soil N and crop yields (Kang et al., 1999; Kwesiga et al., 1999; Hartemink et al., 2000; Akinnifesi et al., 2006, 2007), the effectiveness of the organic N applied is relatively lower than inorganic fertilizer (Mulongoy and van der Meersch, 1988; Akinnifesi et al., 1997). The low N uptake by crops from the applied organic N is attributed to asynchrony between the N released by organic materials and N demand by the crop. Lack of synchrony can arise from two situations: (i) when mineral N supply comes too late to meet the crop demand, in the case of slowly decomposing materials, (ii) the N supply comes too early for the crop demand, in the case of fast decomposing organic materials releasing N in excess of current plant demand (Myers et al., 1994, 1997).

Myers et al. (1994) suggested that synchrony between N release and demand by the crop may be achieved by combining low and high quality organic materials. Handayanto et al. (1995, 1997) examined the effects of mixing high and low quality organic materials in labora-

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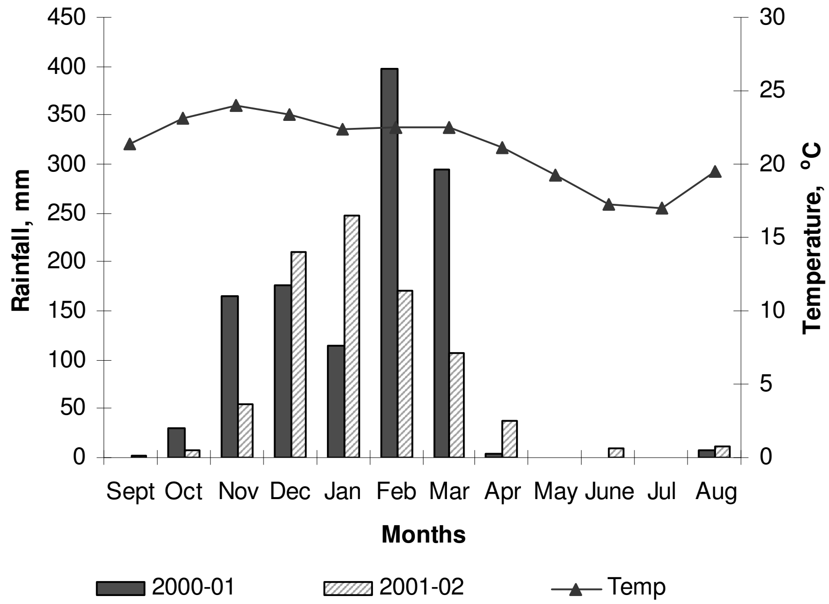

Figure 1. Monthly rainfall and temperature distribution pattern during 2000-01 and 2001-02 seasons.

tory and glasshouse experiments, and concluded that N release pattern of high quality organic materials can be manipulated by combining them with low quality material. Becker et al. (1994) and Whitbread et al. (1999) demonstrated that mixtures of sesbania prunings or pigeon pea leaves with rice straw/rubbles increased the yield of flooded rice more than sesbania prunings alone. These results point at complex relations between N release by crop residue and prunings and N demand by the specific crop.

Information obtained from glasshouse and laboratory experiments may not directly be applied to explain the complex decomposition and N release patterns under field conditions. Most glasshouse experiments do not last long enough as to allow for complete decomposition and also most large soil fauna is usually excluded. In flooded rice (Ladha et al., 1997; Whitbread et al., 1999) mineralization occurs under anaerobic conditions and the processes governing mineralization may not be the same as in the upland where aerobic conditions dominate. There is also a knowledge gap in the decomposition patterns of the mixtures and interaction between high and low quality organic materials.

We tested the following two hypotheses: (1) decomposition patterns of mixtures of tree prunings and crop residues are not interactive but additive; (2) mixtures of high and low quality organic materials can increase N uptake and yield of the current crop when the immobilized N is released within the course of maize growth. The specific objectives were (1) to determine the decomposition patterns of crop residues and tree legume prunings, and (2) to increase the understanding of the interactions between low quality crop residues and high quality tree legume prunings with respect to N uptake and yield of maize.

MATERIALS AND METHODS

Study site description

The experiments were conducted at Makoka Agricultural Research Station, Zomba, Malawi during cropping seasons of 2001-02. The soil had 38% clay, 54% sand and the chemical characteristics were: pH (water) = 5.6; organic carbon 9.3 g/kg; P-Olsen = 10.3 mg/kg; Exchangeable K = 3.7 mmol/kg, Ca = 17.3 mmol/kg and Mg = 4.2 mmol/kg. The soil was characterized as Ferric Lixisols (FAO). The rainfall during the two seasons of our study was 1200 mm in 2000/01 and 800 mm in 2001/02. Figure 1 shows the rainfall distribution pattern and temperature variations for the experimentation period.

In situ decomposition and mineralization experiments

The performance of high quality legume pruning, low quality crop residues and their mixtures were studied in two ways: i) in situ incubation experiments monitoring mass disappearance of organic material in litterbags, and changes in soil mineral N in aluminum cores, and ii) agroforestry field trial focusing on maize yield, N uptake, and mineral N assessments.

Decomposition of organic materials in litterbags

The litterbag experiment was conducted in the 2000-2001 season. The experimental design was a randomized complete block. The treatments used include: (1) two high quality residues: 15 g *Gliricidia sepium* (Gs) prunings per bag, and 12 g *Sesbania sesban* (Ss) prunings per bag; (2) three medium quality residues: 7.5 g pigeon pea leaves (Pea-L), 2.5 g pigeon pea roots (Pea-R), 10 g

Table 1. Mass fractions of N, P, K and C (mg/g), and C:N ratio of the organic materials incorporated in the soil.

Organic material	N	P	K	C	C:N
Sesbania	34.4	1.2	11.7	488	15
Gliricidia	28.9	4.0	12.2	467	16
Pigeon pea fresh leaves	32.4	1.4	11.6	463	14
Pigeon pea litter	16.3	1.1	9.8	472	29
Pigeon pea roots	8.6	0.6	13.7	490	57
Maize stover	4.7	0.6	7.9	405	86

pigeon pea leaves + roots (Pea-LR), and (3) two low quality residues: 7.5 g maize stover (Stover-1), and 15 g maize stover (Stover-2).

The organic materials were chopped to about 2 cm long pieces and were placed in 20 x 20 cm nylon bags with 2 mm mesh. The litterbags were lightly buried in the field on 2nd December 2000. The litterbags were sampled after 14, 21, 42, 63, 70 and 84 days, at two samples per treatment during each sampling time. Soil particles and roots growing in the litterbags were manually removed and the remaining organic material was washed with distilled water and oven dried at 75°C for 48 h. The dry-matter of the remaining biomass was determined. Decomposition rate constants were calculated assuming first-order reactions:

$$Y_t = Y_0 e^{-kt} \quad (1)$$

Where Y_0 is the original mass, Y_t is the remaining mass at time t, and k is the decomposition constant. In a plot of $\ln Y_t$ against time t, the slope of the linear regression line is k (the decomposition constant).

Field trial

The treatment combinations of high and low quality materials were laid in randomized complete block arrangement with three replications. (i) Two high quality residues were used: sesbania pruning (1.5 t ha^{-1}) and gliricidia pruning (3 t ha^{-1}), ii) three medium quality residues include pigeon pea leaves (Pea-L) consisting of green leaves (0.64 t ha^{-1}) + litter (0.86 t ha^{-1}), pigeon pea roots (Pea-R) (0.5 t ha^{-1}), Pea-L (1.5 t ha^{-1}) + roots (Pea-LR) (0.5 t ha^{-1}), iii) two low quality residues including 1.5 t ha^{-1} maize stover (Stover-1) and 3.0 t ha^{-1} maize stover (Stover-2). The gross plot size was 11.7 x 12.0 m and the net plot size was the interior 6.7 x 8.6 m. Each plot with trees consisted of 8 rows of leguminous trees with 13 trees per row.

Management and chemical properties of organic materials

The field trial was conducted in 2000-01 and repeated in 2001-02 at the same site, maintaining the treatments in same plots. Maize and pigeon pea were planted on the same dates on 16th November 2000 in 2000-01 season, and on 20th November 2001 for 2001-02 season. In the first season (2000-01), 3 months gliricidia coppices and 10 months old sesbania trees were cut and incorporated on 11th November 2000. In the second season (2001-02), trees were cut and incorporated in the soil on 6th November 2001. Tree leaves and small twigs were stripped and incorporated on the ridge while fresh. Due to low biomass yield of sesbania the amount of biomass applied was reduced to 1.5 ton DM/ha in both years.

Pigeon pea biomass was cut and incorporated at the same time as gliricidia and sesbania biomass. Pigeon pea litter that had accumulated on the ground during the growing period was swept and removed from the plots where roots only were applied. The pigeon pea roots growing within the ridge (30 cm soil depth) were removed from the plots where pigeon pea leaves only were applied. Pigeon pea leaf biomass consisted of leaf litter (leaves that dropped during the season) and the green leaves harvested at the time of cutting.

The gliricidia, sesbania and pigeon pea samples were collected a week before cutting for determination of dry-matter; sampling was repeated at the time of incorporation of tree prunings for chemical analysis.

The nutrient mass fractions are tabulated in Table 1. Gliricidia, sesbania and pigeon pea green leaves had high N content and low C: N ratio. Maize stover had low N and a wide C: N ratio. The mass fractions of N, P and K in the crop residues decreased in the order of pigeon pea leaves, pigeon pea roots and maize stover. Since pigeon pea green leaves were combined with litter, the combined pigeon pea leaf material was considered as medium quality material. The amounts of organic N applied via the organic materials are presented in Table 2.

Maize yield and N uptake

Maize was harvested in the first week of May. Maize yield was measured from the net plot. All maize stover harvested in the net plot was weighed and the weight was recorded. A sample was taken to determine dry matter content and used to correct the weight of the dry-matter yield of stover. After shelling the maize cobs, grain and rachis were weighed separately and their weights were recorded. Samples of grain and rachis were collected and dried in an oven at 72°C for 48 h and their dry-matter contents were determined. The dried plant materials were finely ground and analyzed for total N following the method of Terminghoff et al. (2000). N present in each of the three parts of the maize plant was calculated as the product of its dry-matter yield and N mass fraction. The Total N uptake reported is the sum of the amounts present in the three plant parts.

Data analysis

Data was analyzed using GENSTAT version 5. Means were separated using the least significant difference (LSD) at 0.05 probability level.

RESULTS

In situ decomposition and mineralization (litterbag)

The weight of tree pruning dry-matter decreased faster than that of the crop residues and their mixtures. After 14

Table 2. Organic N and P (kg ha^{-1}) applied in the field trial with the various treatments.

Treatment†	Organic N			Organic P			Weighted mean C:N		
	Control	Ss	Gs	Control	Ss	Gs	Control	Ss	Gs
Control	-	52	87	-	2	12	-	15	16
Pea-L	35	87	122	2	4	14	20	17	17
Pea-LR	39	91	126	2.3	4.3	14.3	24	19	19
Pea-R	4	56	91	0.3	2.3	12.3	57	17	18
Stover-1	7	59	94	0.9	2.9	12.9	86	23	21
Stover-2	14	66	101	1.8	3.8	12.8	86	30	26

†Control = No tree prunings, no crop residues; Pea-L = pigeon pea leaves; Pea-LR = pigeon pea leaves and roots; Pea-R = pigeon pea roots; Stover 1 = 2.5 t of maize stover; and Stover-2 = 5 t maize stover.

Table 3. Maize grain yield and total dry-matter yield (t ha^{-1}) as a function of the addition of high quality and low quality organic materials.

Treatment†	2000-01				2001-02			
	Control	Sesbania	Gliricidia	*Mean*	Control	Sesbania	Gliricidia	*Mean*
Grain yield								
Control	0.85 c	2.0 a	3.1 a	*2.0*	1.0 b	1.9 a	3.0 a	*2.0*
Pea-L	2.7 a	2.2 a	3.7 a	*2.9*	1.6 a	2.2 a	3.1 a	*2.3*
Pea –LR	2.4 a	2.2 a	3.5 a	*2.7*	1.5 a	2.0 a	2.5 b	*2.0*
Pea-R	1.7 b	1.5 a	3.1 a	*2.1*	1.3 a	1.4 b	2.4 b	*1.7*
Stover-1	1.5 bc	2.2 a	3.4 a	*2.4*	0.7 b	1.2 bc	2.1 bc	*1.3*
Stover-2	1.4 bc	1.9 a	3.1 a	*2.1*	0.7 b	1.0 c	1.7 c	*1.1*
Mean	*1.7*	*2.0*	*3.3*	*2.4*	*1.1*	*1.6*	*2.4*	*1.7*
Total dry-matter yield								
Control	1.9 c	3.9 a	6.4 a	*4.1*	2.1 bc	3.9 a	6.1 ab	*4.0*
Pea-L	5.9 a	4.5 a	7.8 a	*6.0*	3.5 a	4.6 a	6.4 a	*4.8*
Pea –LR	5.1 a	4.7 a	7.2 a	*5.7*	3.2 a	4.4 a	5.1 bc	*4.4*
Pea-R	3.5 b	3.2 a	6.5 a	*4.4*	2.6 b	2.9 b	4.8 bc	*3.5*
Stover-1	3.0 bc	4.6 a	7.1a	*5.5*	1.6 cd	2.5 b	4.1 cd	*2.7*
Stover-2	2.9 bc	3.9 a	6.3 a	*4.4*	1.5 d	2.2 b	3.4 d	*2.4*
Mean	*3.7*	*4.2*	*7.2*	*5.0*	*2.4*	*3.4*	*5.0*	*3.4*

†Control = No tree prunings, no crop residues; Pea-L = pigeon pea leaves; Pea-LR = pigeon pea leaves and roots; Pea-R = pigeon pea roots; Stover 1 = 2.5 t of maize stover; and Stover-2 = 5 t maize stover.

days 56% of gliricidia and 59% of sesbania dry-matter remained in the litterbags whereas for the crop residue the dry-matter ranged from 71 to 97%. At the end of the experiment, after 84 days, most of the dry-matter of the tree prunings had decomposed and only 8% of gliricidia and 9% of sesbania dry-matter was left in the litterbags; from the crop residues alone 12 - 36% remained and from the mixtures between 10 and 23%.

Maize yield and N uptake

Table 3 presents the maize grain and total dry-matter yields. In both seasons maize grain yield was highest in gliricidia treatments, but also sesbania significantly ($P < 0.001$) increased maize grain yield. In 2000-01, maize yield in treatments with Pigeon pea residues alone (NTP) ranged between 1.7 and 2.7 t ha^{-1}, which was significantly ($P = 0.05$) higher than the control (0.85 t ha^{-1}) but the yields with stover did not differ from control. Maize grain yield was generally higher in Gs/Pea-L, Gs/Pea-LR and Gs/Stover-1 than Gs alone in 2000-01 season but this difference was statistically not significant. In 2001-02, maize stover (Stover-1 and Stover-2) reduced maize yield by 30% below the control, but the difference was not significant. In 2001-02, mixtures of tree prunings with Stover-1 and Stover-2 had significantly lower maize grain and dry-matter yield than tree prunings alone or mixed with Pea-L, while mixtures with Pea-LR and Pea-R took a position in between. Generally, maize yield was lower in 2001-02 than in 2000-01 season. Analysis of variance showed significant effects of the addition of high quality

Table 4. Total N uptake (kg ha^{-1}) in the above-ground crop.

Treatment†	2000-01				2001-02			
	Control	Sesbania	Gliricidia	*Mean*	Control	Sesbania	Gliricidia	*Mean*
Control	22 c	52 a	78 b	*51*	19 c	41 ab	64 a	*41*
Pea-L	58 a	57 a	96 a	*70*	34 a	45 a	66 a	*49*
Pea -LR	64 a	54 a	81 b	*67*	30 ab	40 ab	54 b	*41*
Pea-R	38 b	43 a	73 b	*51*	25 b	30 bc	53 b	*36*
Stover-1	36 b	54 a	75 b	*63*	16 c	26 c	46 bc	*29*
Stover-2	34 b	49 a	72 b	*52*	15 c	23 c	38 c	*25*
Mean	*42*	*52*	*83*	***59***	*23*	*34*	*53*	***37***

†Control = No tree prunings, no crop residues; Pea-L = pigeon pea leaves; Pea-LR = pigeon pea leaves and roots; Pea-R = pigeon pea roots; Stover 1 = 2.5 t of maize stover; and Stover-2 = 5 t maize stover.

and low quality organic materials. Also their interaction on maize was significant, but far less important than the main effects.

Application of tree prunings significantly ($P < 0.001$) increased N uptake and was highest in gliricidia pruning treatments (Table 4). Amongst the crop residue treatments, Pea-L had highest N uptake, and N uptake from the mixtures of the Pea-L with tree prunings was higher than that from tree prunings alone. N uptake by maize in the mixtures of tree prunings with Pea-R, Stover-1 and Stover-2 was statistically not different from the N uptake in the plots where only tree pruning were applied in 2000-01 but N uptake in these plots was lower than in tree prunings plots in 2001-02 season.

The effects on N uptake of tree prunings were much stronger than those of crop residues; both were highly significant again their interactions were significant in both seasons (at $P = 0.029$ in 2000/01 and $P = 0.01$ in 2001/02), but less important than the main effects.

Decomposition rate constants

Figure 2 shows the graphs of natural log of the fraction of remaining weight of dry matter plotted against time t (days). The average decomposition rate constants of the organic materials for the whole period are given by gradient of the linear regression lines and are tabulated in Table 5. A decomposition rate constant per day of pure materials was highest for Gs (2.93%) followed by Pea-L (2.64%), sesbania (2.28%), while that for Stover-2 (1.80%) was lowest. Decomposition rate constants of mixtures of tree prunings and crop residues were somewhere in between the decomposition rate constants of the individual components but not necessarily their average. The decomposition rate constant of Stover-2 was less than that of Stover-1 despite that the materials were from the same source.

Expected mean decomposition constants for the mixtures were derived from expected remaining amounts of dry matter in the mixtures (Table 5). The measured decomposition rate constants were on average 89% of the expected values.

Table 5. Decomposition rate constants (%day^{-1}) of tree prunings, crop residues and their mixture in litterbag, as derived from Figure 2.

Treatment†	Control	Sesbania	Gliricidia
Control		2.28	2.93
Pea-L	2.64	2.11	2.83
Pea-LR	2.01	1.69	2.21
Pea-R	1.38	1.63	1.98
Stover-1	2.14	2.19	2.50
Stover-2	1.80	1.73	1.96
[a]Expected mean decomposition constants			
Pea-L		2.42	2.82
Pea-LR		2.14	2.45
Pea-R		2.05	2.52
Stover-1		2.22	2.58
Stover-2		1.98	2.21

[a]Expected mean decomposition constant for the mixtures are derived from expected remaining amounts of dry-matter in the mixture.
†Control = No tree prunings, no crop residues; Pea-L = pigeon pea leaves; Pea-LR = pigeon pea leaves and roots; Pea Pea-R = pigeon pea roots; Stover 1 = 2.5 t of maize stover; and Stover-2 = 5 t maize stover.

Fractions of N immobilized

The N fraction immobilized by the Pea-R and Stover were determined graphically (Figure 3), the regression coefficients, R-square and N fraction immobilized had been reported in Table 6. Absolute amounts of N fraction immobilized were also calculated for each mixture with tree prunings (Table 7). The average N fraction immobilized found by the two methods differed only in the first season (2000-01) for the Stover but were same in the second season, 2001-02. From both methods it is clear that more N was still immobilized in 2001-02 by the time of harvest than in 2000-01. Considering the first method

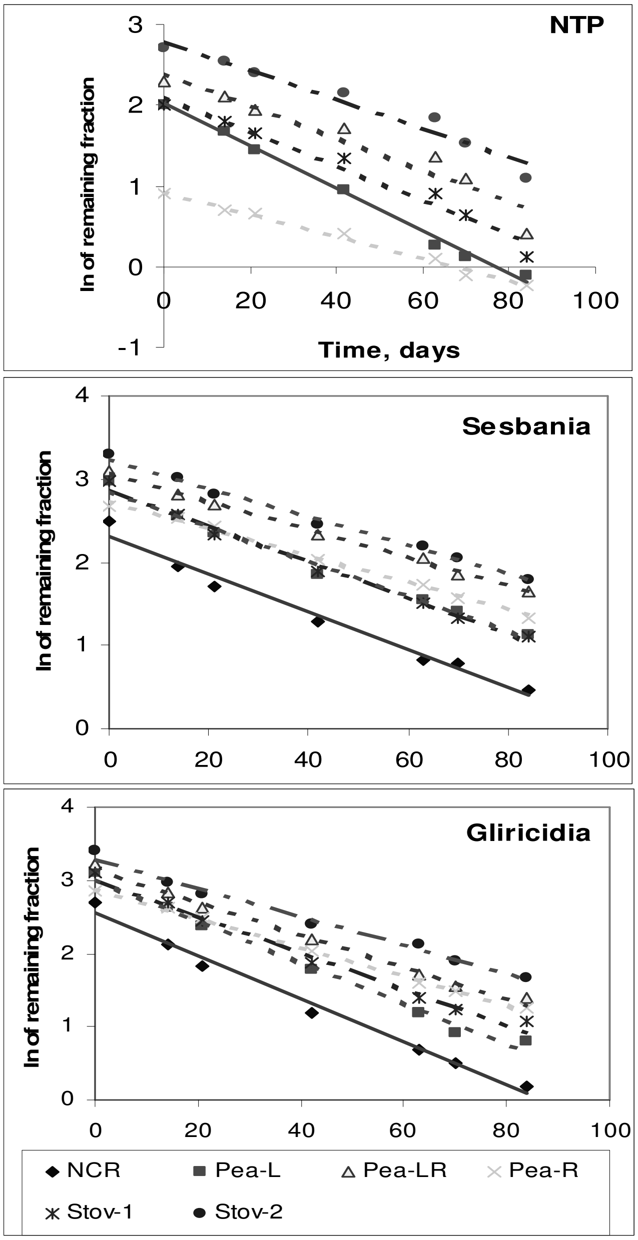

Figure 2. Derivation of decomposition constants of tree prunings, crop residues and their mixtures from the relation of the natural log of remaining mass fraction and time (days). NCR = control plot, without crop residues; NTP = no tree pruning plots; Pea-L = pigeon pea leaves; Pea LR = pigeon pea leaves and roots combined; Pea R = pigeon pea roots; Stov 1 = stover rate 1; and Stov 2 = stover rate 2.

of regression, Stover-2 had the highest N fraction immobilized in both seasons, 15% in the wetter season (2000-2001) and increased to 35% in the drier season (2001-2002). During the wetter season the crop residues remineralized more N that was immobilized early in the season resulting in high N uptake by the maize than in the next season where less N was remineralized hence reducing N uptake.

Interaction between maize stover and tree prunings

Tables 4 and 5 showed a significant tree prunings x crop residues. We assumed this was because pea leaves and roots were quite different materials than maize stover. Maize stover had low N content and wide C:N ratio, and gave the lowest decomposition rate constants. Therefore, an analysis of variance was done separately for tree prunings and maize stover. The interaction between tree prunings and maize stover for the yields and uptake parameters was not significant in 2000-01 season, it was significant ($P < 0.001$) in 2001-02 season. In the second season N immobilized early in the season might not have been remineralized yet within the time course of crop's demand because of low rainfall, and hence yield and N uptake are reduced by stover. The difference between stover-1 and Stover-2 is depending on the type of tree pruning treatments. Such a relation is not seen in season 2000-01.We believe that the interaction observed in the second season was due to the influence of rainfall. Lack of statistical interaction between stover and tree prunings on maize yield parameters in the first season is due to the fact that N immobilized early in the season had been released within the time of demand by the crop to such an extent that the difference between Stover-1 and –2 has not been affected any more by the tree pruning treatments.

DISCUSSION

The decomposition rate constants of the tree prunings obtained in this study (Table 5) are within the range reported earlier by other authors. For instance, the decomposition rate constants for gliricidia have been found to range between 2.40 and 3.10% day^{-1} (Budelman, 1988; Mwiinga et al., 1994), while for sesbania a rate constant of 2.10% day^{-1} has been reported by Mwiinga et al. (1994). The rate constants of gliricidia seem to be related to the pretreatment of the prunings. Fresh materials were used in both Budelman (1998) and in our study, yielding relatively high (2.93 and to 3.10% day^{-1} respectively), whereas some researchers (Mwiinga et al., 1994) had used oven dried prunings. The rate constants of the tree prunings tended to decline with time.

Apparently, the high N content of the tree prunings and the easily decomposable compounds facilitated the initial fast decomposition of the leafy materials and since the remaining twigs were more lignified and recalcitrant to decomposition the decomposition rate decreased. Berg and Meentemeyer (2002) alluded the decrease in decomposition rate constant of organic materials to chemical changes in the substrate itself and the succession in microorganisms able to compete for substrate with a given chemical composition. On the other hand the decomposition of the crop residues was low initially but tended to increase from 63 days onwards. The initial slow decomposition could be influenced by the N deficiency in

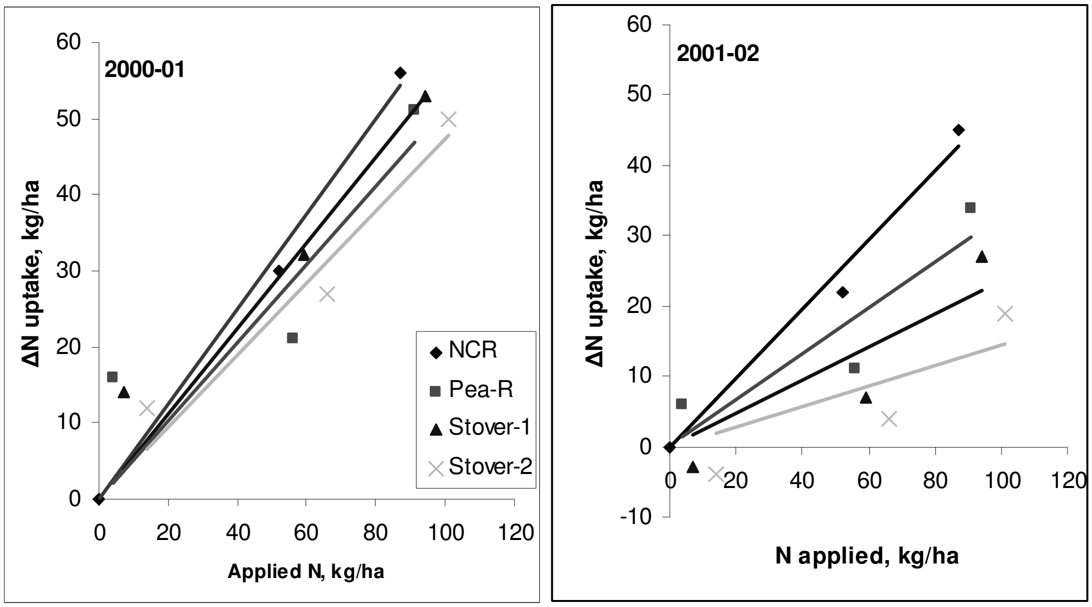

Figure 3. Relationship between ΔN uptake and equivalent N applied for NCR (Control), Pea-R and Stover determined at the time of harvest. NCR = Control plot, without crop residues, Pea-R = pigeon pea roots.

Table 6. Values of regression coefficient a, and of R-square of regression coefficient equations (y = ax) relating ΔN uptake at the time of harvest to the applied equivalent fertilizer N.

Treatment†	Regression coefficient 'a'	R-square	Fraction of N immobilized
2000-01			
Control	0.63	0.99	
Pea-R	0.51	0.62	0.14
Stover-1	0.56	0.87	0.06
Stover-2	0.47	0.93	0.15
2001-02			
Control	0.49	0.93	
Pea-R	0.33	0.79	0.17
Stover-1	0.24	0.93	0.26
Stover-2	0.14	0.68	0.35

†Control = No tree prunings, no crop residues; Pea-R = pigeon pea roots; Stover 1 = 2.5 t of maize stover; and Stover-2 = 5 t maize stover.

Table 7. Absolute fraction of immobilized N.

Treatment†	Sesbania	Gliricidia	Mean
2000-01			
Pea-R	0.17	0.10	0.13
Stover-1	-0.04	0.06	0.01
Stover-2	0.06	0.12	0.09
2001-02			
Pea-R	0.21	0.13	0.17
Stover-1	0.29	0.21	0.25
Stover-2	0.35	0.30	0.32

†Control = No tree prunings, no crop residues; Pea-R = pigeon pea roots; Stover 1 = 2.5 t of maize stover; and Stover-2 = 5 t maize stover.

crop residues that might have affected the rapid colonization of the soil microbes.

The lower N recoveries in 2001-02 than in 2000-01 suggest that decomposition, mineralization, immobilization and remineralization were dependent on the amount of rainfall. In the first season, 2000-01, when the rainfall was 1200 mm N uptake by maize in mixtures of tree prunings with Pea-R and Stover were not significantly different from tree prunings only whereas during the drier season, 2001-02 (800 mm), N uptake in Pea-R and Stover mixtures was significantly (P = 0.05) lower than in tree prunings only. We suggest that this effect was the influence of the drier conditions retarding the processes of decomposition, mineralization and remineralization, and it was not a special interaction between crop residues and tree prunings.

Increasing the rate of stover in the mixtures with tree prunings reduced maize grain and dry-matter yields. Increasing stover rate increased C: N ratio in the soil hence resulting in N immobilization making it unavailable for crop uptake. The decomposition by Stover-2 might have been slower and hence remineralization of N came too late for the crop demand thus jeopardizing the synchrony of the N release and uptake by the crop. The slow remineralization of N by Stover-2 is reflected by the high fraction of N immobilized at harvest (Table 5). Also in a pot experiment (Makumba et al., 2007) found that the fraction of N immobilized increased when the proportion of stover in the mixture was increased. Becker et al. (1994) showed that increasing rice straw in the sesbania-rice straw mixture decreased the net N mineralization. In a pot experiment Handayanto et al. (1997) also found that N recovery by maize decreased when the proportion of low quality peltophorum prunings in the gliricidia-peltophorum pruning mixture was increased. These results suggest that mixture of 3 t ha^{-1} gliricidia prunings with 2.5 t ha^{-1} maize stover (or 2:1 prunings: stover ratio) would better synchronize the N release by the organic materials and N demand by maize than the higher rate of 3 t ha^{-1} stover.

Conclusion

The decomposition pattern of the tree prunings and crop residues followed the order: Gliricidia > Pigeon pea leaves > Sesbania > mixtures (tree prunings/crop residues) > Stover-1 > Stover-2 > Pigeon pea-roots. The decomposition rate constants of the mixtures of the high quality tree prunings and low quality crop residues decreased with the increasing amount of crop residues. There was no special interaction between high quality tree prunings and maize stover; the apparent statistical interaction can be expected as an effect of rainfall.

Remineralization of N immobilized early in the season was related to the amount of rainfall. During the drier season Pigeon pea-roots, Stover-1 and Stover-2 immobilized 17, 26 and 35% N, respectively resulting in reduction of maize N uptake and yield whereas in the wetter season N fraction immobilized was 4 to 7 times lower than in the drier season and N uptake and maize yield were relatively high. This result confirms our second hypothesis that mixtures of high and low quality organic materials can increase N uptake and yield of the current crop when the immobilized N is released within the course of maize growth. It is therefore concluded that mixing of high quality tree prunings with low quality crop residues may enhance the decomposition of low quality crop residues but there is no special interaction, and remineralization of N immobilized early in the season by the low quality organic materials is stimulated by well distributed rainfall.

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