NITROGEN FIXATION BY *GLIRICIDIA SEPIUM:* DECOMPOSITION OF ITS LEAVES IN SOIL AND EFFECTS ON SWEET-CORN YIELDS

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Abstract

Nitrogen fixation by *Gliricidia sepium* subjected to three pruning regimes (one, two or four cuts per year) was measured using the ^{15}N-dilution technique with *Cassia siamea* as the reference species. Over a 4-year period, estimates of the fraction of N derived from fixation, generally <50%, indicated that field-grown *G. sepium* is a low N_2 fixer. *Gliricidia sepium* leaves were placed in litter-bags, buried in an ultisol and sampled at intervals over 70 days. The half-life for dry matter was 17 days, and about 60% of the N was lost within 10 days; K and Ca were the most rapidly released nutrients, with half-lives of only 1 and 3 days, respectively. The N contributions from *G. sepium* leaves and roots to alley-cropped sweet corn were quantified by the ^{15}N-dilution technique over three growing seasons. The application of leaves with roots resulted in increased N uptake and dry matter yield in corn. Below-ground competition between hedgerow and corn, assessed using ^{32}P with the third crop, occurred under conditions of low nutrient-availability. The data imply that there is no advantage of the cut-and-carry system over permanent hedgerows, provided that prunings are applied at the time of nutrient demand in the crop.

1. INTRODUCTION

The traditional land-use system of shifting cultivation has proved to be unsustainable in the tropics. The fallow period is becoming increasingly short due to demographic pressure and land-tenure systems, resulting in rapid declines in soil fertility and productivity, with deleterious environmental consequences, mainly soil erosion [1,2]. The decline in availability of nutrients, especially N, is not mitigated by the use of chemical fertilizers where available [3,4], due to low organic-matter inputs and high losses of N [5,6].

Alley-cropping has been proposed as an alternative to shifting cultivation [7]. This usually involves intercropping leguminous trees or shrubs with cereals. The former are pruned regularly to prevent shading and reduce competition with the crop, the productivity of which is maintained through application of the prunings to the soil. In addition, root residues are suspected of contributing substantially to crop-nutrient availability. This system has been reported to improve soil fertility and nutrient uptake, and to reduce soil erosion [8,9].

Legume residues are generally known to improve crop productivity by enhancing the availability of soil N in addition to supplying plant-available N [10]. Depending on the nature of the materials, two modes of action are distinguished, namely a direct effect on nutrient supply and an indirect effect on the soil micro-climate. Plant materials of low C:N, lignin and polyphenol decompose rapidly and are readily available sources of nutrients for crops. There is need to develop management options to ensure that nutrient release from green manure matches crop needs while minimizing losses [11-13]. Poor-quality residues (high C:N, lignin and polyphenol) also improve crop performance, through positive effects on the soil microclimate, even when applied as mulch [9,14,15]. The long-term build-up of soil organic matter has been established to be more important than the immediate supply of nutrients [16].

Although the potential for alley-cropping is widely acknowledged, information on competition for nutrients between the hedgerows and crops is still lacking. There have been reports of substantial proportions of the residue N being recovered in hedgerow above-ground biomass [17,18]. This phenomenon and the immobilization of N in soil organic matter are believed to have contributed to low utilization of residue N in first maize crops in *Leucaena* alley-cropping systems [19]. However, this N becomes available to subsequent crops through pruning of hedgerow regrowth, application to the soil, and mineralization.

Nitrogen-fixing trees can play a special role in alley-cropping systems through the ability to thrive in N-deficient soils [20]. *Gliricidia* species in particular have potential due to their fast-growing characteristic, however, N_2-fixing ability, as measured by acetylene reduction, was found to be poor [21]. On the other hand, research using the ^{15}N-dilution technique indicated that *G. sepium* was comparable to *Leucaena leucocephala,* which is regarded as a high N_2 fixer [21]. Danso et al. [20] found that *G. sepium* derived 72% of its N from fixation (i.e. from the atmosphere, Ndfa), and Liya et al. reported 85% Ndfa when *G. sepium* was grown in concrete cylinders sunk 1 m into the ground [22].

The potential importance of nutrient-rich green manures in building and sustaining soil fertility and crop productivity in low-input agricultural systems is now widely acknowledged [8,10,23]. These organic amendments not only contribute plant-available nutrients during decomposition by soil micro-organisms, but also improve soil physico-chemical and biological properties [8,24]. These processes are dependent on the quality of the material, on climatic factors, and on the nature of the soil flora and fauna [11,25-27].

A direct relationship exists between decomposition rate and initial N or lignin and soluble polyphenols in the green manure. High initial N, low C:N, (lignin+polyphenol):N and polyphenol:N ratios favour high rates of decomposition, fresh leguminous leaves for example [12,28-30]. Thus, nutrient releases differ according to the quality of the organic material, in extent and pattern. Previous investigations have been directed at the dynamics of release and availability of N during green-manure decomposition. More information on release patterns and interactions with other factors is required for the development of effective nutrient-management practices for low-input cropping systems.

This research had several objectives.

- To evaluate the effects of successive cutting on N_2 fixation by field-grown *Gliricidia sepium* over four years, using the ^{15}N-dilution technique with *Cassia siamea* as the reference crop.
- The elucidation of decomposition and nutrient-release patterns of fresh leaves of *G. sepium.*
- The quantification of *G. sepium* leaf N used by alley-cropped sweet corn using the ^{15}N dilution technique.
- To assess below-ground competition for P between *G. sepium* hedgerows and alley-cropped sweet corn.

2. MATERIALS AND METHODS

2.1. Nitrogen fixation by *G. sepium*

A field experiment was conducted at the Puchong experimental site of the Department of Soil Science, Universiti Putra, Malaysia, where the climate is humid tropical with a mean annual rainfall of 2,100 mm. The soil at the trial site is classified as a kandic tropudult with the following characteristics: pH(H_2O) 5.2; total N 0.16%, Bray-2 extractable P 29 mg kg^{-1}, ammonium acetate exchangeable K, Ca and Mg of 120, 376 and 90 mg kg^{-1}, respectively. Plots of 5×5 m were marked out, with 0.5 m between, and basal fertilizers of 100 kg P ha^{-1} and 100 kg K ha^{-1} were applied.

Three-month-old *Gliricidia sepium* seedlings were transplanted from the greenhouse at 1×1 m. *Cassia siamea* plants, as the reference, were similarly transplanted. The centre 3×3 m area in each plot was trenched to a depth of 1 m and lined with plastic sheet, and the original soil replaced. This area was evenly applied with 3 g N as ammonium sulphate enriched with ^{15}N at 10% atom excess. The same rate of N as unenriched ammonium sulphate was applied around the trenched area. Trees in the trenched area were divided into one row to be pruned at 1 m above the ground level every 3 months, one row to be pruned every 6 months, and the remaining row to be cut on a yearly basis (designated "unpruned"). The same treatments were applied to the *C. siamea*. The plots were established for trees to be harvested at 1, 2, 3 and 4 years after transplanting. The ^{15}N for the plots to be harvested at the end of the second, third and fourth years was applied at the beginning of the respective year, as described above. There were five replications, randomly arranged.

At the end of each year, individual trees from each cutting-regime from two replications were dug out, separated into leaves, stem and root, weighed and chopped using a garden shredder, and sub-sampled. The trunks of large trees were cut into small pieces using an electric saw, and the saw dust used as the sub-sample. The sub-samples were weighed and dried in a forced-air oven at 65°C until constant weight was achieved. The samples were finely ground and mixed again. Total N and N-isotope ratios were determined at the FAO/IAEA Soil Science Unit, Seibersdorf, Austria, with a 1500 Carlo Erba Automatic Nitrogen Analyzer coupled to a SIRA mass spectrometer. The isotope-dilution equation [31] was used to calculate the fraction of N derived from fixation, with *C. siamea* as the non-fixing reference. The significance ($P \leq 0.05$) of differences between mean values was determined by analysis of variance using a SAS-PC package [32].

2.2. *Gliricidia sepium* leaf decomposition

This experiment was carried out also at the Puchong experimental site of Universiti Putra. The temperature ranged between 19 and 36°C with average relative humidity of 97% during the experimental period. The rainfall pattern is shown in Fig. 1. The soil used is of the Bungor series (typic paleudult) in an undulating land-form with the following properties at 0-15 cm depth: pH (water, 1:2.5) 4.6, pH (KCl, 1:2.5) 3.6, 4.4 mg kg^{-1} Bray-1 P, 0.013% N, 1.4% organic C, cation exchange capacity (CEC) of 5.7 cmol(+)kg^{-1}, and exchangeable K, Ca and Mg values of 0.16, 0.07 and 0.08 cmol(+)kg^{-1}, respectively.

Two-hundred g of fresh *G. sepium* leaves were placed in plastic litter-bags, 30×40 cm, with a mesh size of 5 mm, and buried 10 cm in the soil. Bags were randomly excavated in fours at 5, 10, 20, 30, 40, 50, 60 and 70 days. Soil was carefully removed by rinsing in water for 1 min, after which the residue was oven-dried at 70°C, milled and then analyzed for C by the Walkley-Black method, for total N by steam-distillation and titration after digestion with salicylic acid-H_2SO_4, and for other nutrients after ashing at 550°C (4 h): P by the molybdate-blue method, and K, Ca and Mg by atomic-absorption spectrometry. The leaf samples were analyzed initially also for lignin and polyphenol content [13].

Data means were computed and compared by analysis, as described above. The following exponential model was fitted:

$$M_t = M_0.e^{-k.t}$$

where

M_0 is the original amount of dry material or nutrient,
M_t is the proportion of dry matter or nutrient remaining after a period of time t, in days,
k is a constant,
t is time.

A plot of time against logarithm of this first-order exponential model was made for each component. These plots revealed that a single negative exponential model did not give best-fit curves for dry matter and nutrient loss. Therefore, non-linear curves were made, the slopes of which give the k values for each component. Half-lives for dry-matter loss and nutrient release were calculated from the best-fit equations.

2.3 Sweet corn alley-cropped with *Gliricidia sepium*

This research was carried out also at the Puchong experimental site. The relative humidity was between 88 and 93% during the experimental period with maximum and minimum temperatures of 36°C and 20°C, respectively. Rainfall averaged around 2,100 mm. The soil was of the Bungor series (typic paleudult), pH(H_2O) 4.6, pH(KCl) of 3.9, organic C (Walkley-Black) of 1.48%, Bray-1 P of 4.39 mg kg^{-1}, 0.06% N, cation exchange capacity (1 *N* ammonium acetate, pH 7.0) of 8.3 cmol(+) kg^{-1}, exchangeable Ca, K and Mg of 0.32, 0.17 and 0.18 cmol(+)kg^{-1} soil, respectively.

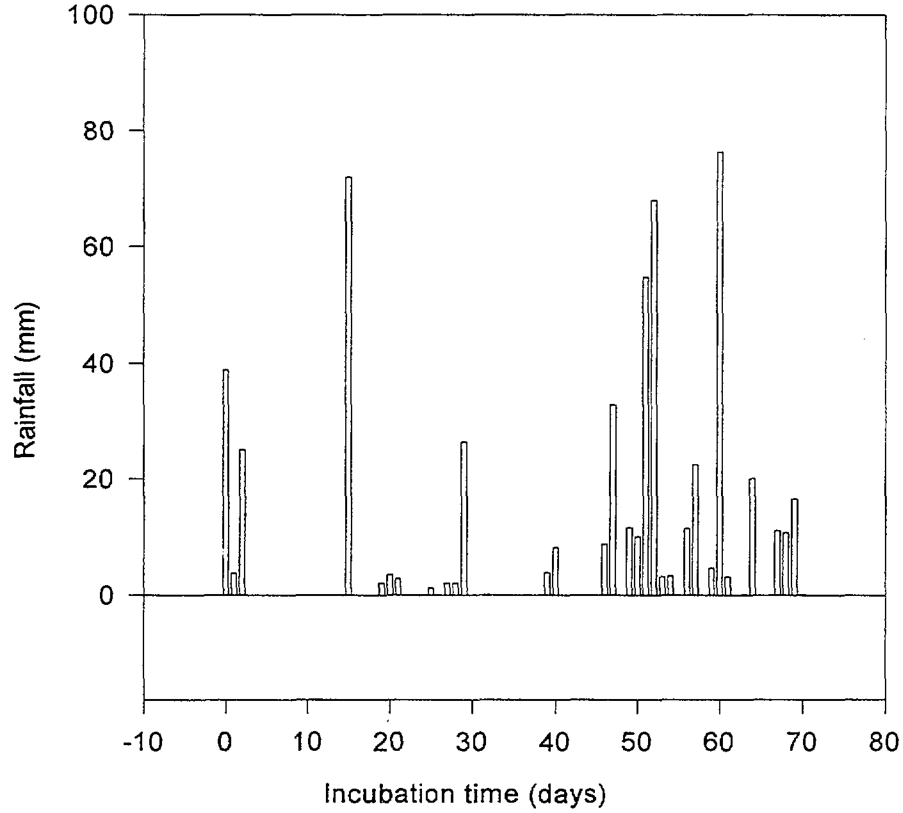

FIG. 1. Rainfall distribution during the period of study.

The following treatments were arranged in a randomized complete-block design with four replicates:

(1) Control without hedgerows.
(2) Control with hedgerows.
(3) Leaf prunings with hedgerows.
(4) Leaf prunings without hedgerows.
(5) Roots without hedgerows.
(6) Roots with hedgerows.
(7) Leaf prunings + roots without hedgerows.
(8) Leaf prunings + roots with hedgerows.

Experimental plots measuring 5×3 m were made and *G. sepium* was planted in May 1992 with a 1×1 m spacing. For the hedgerow plots, *G. sepium* was planted on the plot edges. Where root incorporation was to be made, *G. sepium* seedlings were planted over the plot at the specified distance, i.e. a total of 20 plants plot^{-1}. Before planting the first crop of sweet corn (*Zea mays* L.) in November 1993 on the root-incorporation plots, the trees were cut below ground level and the stumps smeared with the herbicide Garlon 250 to prevent regrowth. The second corn crop was established in October 1994 and the third in January 1996 on these plots with leaf prunings added.

Trees in hedgerow plots were pruned at a height of 1 m. The leaf material had an average composition of 4.2% N, 12% lignin, 2.3% polyphenol, 39% C, 0.88% Ca, 2.6% K and 0.16% P. Lime was applied at 2 t ha^{-1} at about 4 weeks prior to planting the second crop. Sweet corn was then planted at intra- and inter-row spacings of 0.25 and 0.75 m, respectively, giving five rows of twenty-five plants (125 plants plot^{-1}). Applications of 100 kg ha^{-1} as triple superphosphate and 120 kg ha^{-1} KCl, were made with the first pruning application. Then prunings, equivalent to 120 kg N ha^{-1}, were incorporated between the maize rows at 0 and 30 days after planting (DAP) for the first crop. Prunings were applied to the second crop at 5 and 30 DAP and to the third crop at 160 kg N ha^{-1} at 21 and 45 DAP. Nitrogen, P and K fertilizers were added as ammonium sulphate, TSP and KCl at equivalent rates to control plots. Supplementary P and K was added to all pruning treatments as TSP and KCl, respectively. The total amounts of major nutrients supplied by the prunings to each crop are shown in Table I.

In the central 1.5×1.5 m area of each plot, (seven plants) ^{15}N micro-plots were demarcated and 40 kg N ha^{-1} was applied as ammonium sulphate enriched in ^{15}N at 10% atom excess with the other fertilizers. For the third crop, additional 1×1 m micro-plots in each centre row were set up in hedgerow plots, to assess the *G. sepium*'s access to ^{32}P applied to the corn. To each micro-plot, 29.6 MBq ^{32}P was added with 5 mg P as carrier (KH_2PO_4) in 200 mL of water. Hedgerow plants, at 1.7, 2.2, 3.2, and 4.2 m from the centre of each micro-plot, i.e. from the designated "point of application," were harvested individually at 4 and 6 weeks after radioisotope application.

TABLE I. QUANTITIES OF NUTRIENTS ADDED AS *G. SEPIUM* PRUNINGS

Nutrient	Quantity added to		
	Crop 1[a]	Crop 2[b]	Crop 3[c]
	(kg ha^{-1})		
Nitrogen	120	120	160
Phosphorus	4.6	4.6	6.1
Potassium	75.5	75.5	101

[a]Added at 0 and 30 days after planting. [b]Added at 5 and 30 days after planting.
[c]Added at 21 and 45 days after planting.

Weeding and irrigation were carried out manually when necessary. The corn plants were harvested at the milk stage of kernel development, approximately 65 days. Three plants from the centre of the ^{15}N micro-plots were cut at ground level, separated into stover and cobs and total fresh weights recorded. Sub-sample fresh weights were noted before drying at 70°C until constant weight was achieved. Yields were obtained by harvesting the three centre rows. Grain yields for crop 1 were insignificant, therefore they were combined with stovers for determination of total dry matter.

Leaf samples of the hedgerow regrowth were collected at 4 and 6 weeks after radioisotope application for Cerenkov counting of ^{32}P activity after ashing at 550°C for 4 h, and dissolving the cooled ash in 2 *M* HCl.

Samples from the corn plants were milled and total N determined by micro-Kjeldahl distillation and titration after salicylic acid-H_2SO_4 digestion. The ^{15}N enrichments in the samples were determined with a NOI-6 analyzer [33] for crop 1, and by mass spectrometry for crops 2 and 3.

Soil samples were collected for analysis from the plots prior to the experiment and before the third crop.

Nitrogen derived from a treatment (NdfT) was calculated using the indirect isotope-dilution method, as follows.

$$\%\text{NdfT} = 1 - \left(\frac{^{15}\text{N a.e. in plant part}}{^{15}\text{N a.e. in control}}\right) \times 100 \qquad (1)$$

Multiplication of (1) by total N gives NdfT in kg ha^{-1}.

Results were subjected to analysis of variance to evaluate treatment effects as above. Differences between means were tested for significance by Duncan Multiple Range Test ($P \leq 0.05$).

3. RESULTS

3.1. Nitrogen fixation by *G. sepium*

3.1.1. *Plant growth and total N*

The total dry matter produced by *G. sepium* pruned four times per year was 2,305 g $tree^{-1}$ in the first year and 1,397, 1,771, 1,443 g $tree^{-1}$ in years 2 to 4, respectively. The re-growth was hindered latterly probably due to shading from surrounding trees.

At the end of the first year, the stem contributed 42% of the total dry weight, while 26% was from roots and 32% from leaves (Table II). For trees pruned twice per year, the stem contributed 57% of the total dry matter, and the leaves and roots consisted of 22% and 21% respectively. Similarly, trees cut only at the end of the first year consisted of 57%, 21% and 21% as stem, leaves and roots, respectively.

In year 2, for *G. sepium* pruned four times per year, total dry matter was 1,397 g $tree^{-1}$ with 764 g (54%) as leaves, 454 g (33%) as stem and 179 g (13%) as roots, whereas trees pruned twice per year had a total dry-mass production of only 505 g consisting of 29% leaves, 34% stem and 37% roots (Table III). Unpruned tree dry weight was 449 g, with much higher root development (75%) than stem (15%) or leaves (10%).

TABLE II. DRY-MATTER YIELDS, N CONCENTRATION AND TOTAL-N YIELDS OF PLANT COMPONENT PARTS. YEAR 1

Treatment	Dry matter					N concentration					Total N				
Species	Harvest no.					Harvest no.					Harvest no.				
Component	1	2	3	4	Total	1	2	3	4	Mean	1	2	3	4	Total
	(g tree^{-1})					(%N)					(g tree^{-1})				
4 cuts per yr															
G. sepium															
Leaf	113	261	102	258	734	4.5	3.6	3.0	3.3	3.6	5.04	9.26	3.04	8.46	25.8
Stem	116	144	316	396	972	1.4	1.0	1.1	0.7	0.95	1.63	1.45	3.48	2.69	9.25
Root				601	601				1.4	1.4				8.41	8.41
			(Total)		(2,307)								(Total)		(43.5)
C. siamea															
Leaf	141	293	83	186	703	3.5	3.2	3.3	2.4	3.0	4.89	9.32	2.75	4.43	21.4
Stem	126	332	305	379	1,142	1.1	0.8	0.9	0.4	0.7	1.35	2.69	2.72	1.52	8.28
Root				344	344				0.6	0.6				1.89	1.89
			(Total)		(2,189)								(Total)		(31.5)
LSD$_{0.05}$	n.s	n.s	102	n.s							1.03	3.15	2.35	5.91	9.92
2 cuts per yr															
G. sepium															
Leaf		326		142	468		3.6		3.2	3.5		11.8		4.50	16.3
Stem		418		784	1,202		0.8		0.8	0.8		3.34		6.35	9.69
Root				443	443				1.2	1.2				5.45	5.45
				(Total)	(2,113)								(Total)		(31.5)
C. siamea															
Leaf		282		230	512		2.6		2.3	2.5		7.28		5.22	12.5
Stem		332		387	719		0.7		0.5	0.6		2.29		1.82	4.11
Root				406	406				0.6	0.6				2.39	2.39
				(Total)	(1,637)								(Total)		(19.0)
LSD$_{0.05}$		224		441								4.43		1.02	3.35
1 cut per yr															
G. sepium															
Leaf				213	213				3.1	3.1				6.54	6.54
Stem				576	576				0.9	0.9				5.41	5.41
Root				213	213				1.2	1.2				2.58	2.58
				(Total)	(1,002)								(Total)		(14.5)
C. siamea															
Leaf				1,070	1,070				2.1	2.1				22.3	22.3
Stem				783	783				0.4	0.4				3.29	3.29
Root				799	799				0.4	0.4				3.28	3.28
				(Total)	(2,653)								(Total)		(28.8)

TABLE III. DRY-MATTER YIELDS, N CONCENTRATION AND TOTAL-N YIELDS OF PLANT COMPONENT PARTS. YEAR 2

Treatment	Dry matter					N concentration					Total N				
Species	Harvest no.					Harvest no.					Harvest no.				
Component	1	2	3	4	Total	1	2	3	4	Mean	1	2	3	4	Total
	(g tree^{-1})					(%)					(g tree^{-1})				
4 cuts per yr															
G. sepium															
Leaf	299	316	122	27	764	3.6	3.6	3.6	3.3	3.6	10.8	11.3	4.4	0.9	27.4
Stem	144	216	68	6	454	1.3	1.6	1.2	1.5	1.4	1.8	3.5	0.8	0.4	6.5
Root				179	179				1.5	1.5				2.7	2.7
		(Total)			(1,397)							(Total)			36.6
C. siamea															
Leaf	164	182	389	55	790	2.6	2.4	2.5	3.7	2.6	4.2	4.4	9.6	2.1	20.3
Stem	90	155	175	25	445	0.6	0.9	0.8	1.4	0.8	0.6	1.4	1.4	0.4	3.8
Root				112	112				0.6	0.6				0.7	0.7
		(Total)			(1,347)							(Total)			(24.8)
2 cuts per yr															
G. sepium															
Leaf		102		42	144		3.8		3.5	3.7		3.9		1.5	5.4
Stem		78		95	173		1.3		1.5	1.4		1.0		1.3	3.3
Root				188	188				1.6	1.6				3.1	3.1
		(Total)			(505)							(Total)			(11.7)
C. siamea															
Leaf		96		27	123		2.6		3.6	2.8		2.5		1.0	3.5
Stem		74		42	115		0.7		1.0	0.9		0.5		1.5	2.0
Root				87	87				0.7	0.7				6.0	6.0
		(Total)			(325)							(Total)			(11.5)
1 cut per yr															
G. sepium															
Leaf				45	45				3.5	3.5				1.6	1.6
Stem				69	69				1.1	1.1				0.8	0.8
Root				335	335				1.7	1.7				5.9	5.9
		(Total)			(449)							(Total)			(8.3)
C. siamea															
Leaf				64	64				3.2	3.2				2.0	2.0
Stem				77	77				0.7	0.7				5.4	5.4
Root				143	143				0.8	0.8				1.1	1.1
		(Total)			(284)							(Total)			(8.5)

TABLE IV. DRY-MATTER YIELDS, N CONCENTRATION AND TOTAL-N YIELDS OF PLANT COMPONENT PARTS. YEAR 3

Treatment	Dry matter					N concentration					Total N				
Species	Harvest no.					Harvest no.					Harvest no.				
Component	1	2	3	4	Total	1	2	3	4	Mean	1	2	3	4	Total
	(g tree^{-1})					(%)					(g tree^{-1})				
4 cuts per yr															
G. sepium															
Leaf	176	162	14	136	620	2.7	3.4	3.8	3.6	3.4	4.78	5.60	5.59	4.94	20.9
Stem	131	137	117	137	522	1.4	1.4	1.3	1.4	1.3	1.86	1.90	1.54	1.90	7.20
Root				629	629				1.1	1.1				7.17	7.17
		(Total)			(1,771)								(Total)		(35.3)
C. siamea															
Leaf	155	144	126	123	548	2.7	2.5	3.1	3.3	2.8	4.12	3.96	4.03	4.04	15.8
Stem	125	125	108	119	477	0.90	0.85	0.91	1.2	0.90	1.13	1.06	0.98	1.38	4.55
Root				1200	1200				0.56	0.56				6.72	6.72
		(Total)			(2,225)								(Total)		(27.0)
2 cuts per yr															
G. sepium															
Leaf		136		643	779		3.5		4.1	3.7		4.80		26.7	31.5
Stem		225		171	396		1.1		1.5	1.3		2.48		2.51	4.99
Root				1679	1679				1.8	1.8				29.6	29.6
		(Total)			(2,854)								(Total)		(66.0)
C. siamea															
Leaf		225		173	398		3.5		2.9	3.2		7.9		5.02	13.0
Stem		108		124	232		0.73		0.91	0.81		0.79		1.13	1.92
Root				1323	1323				0.65	0.65				8.60	8.60
		(Total)			(1,953)								(Total)		(23.5)
1 cut per yr															
G. sepium															
Leaf				336	336				3.6	3.6				12.2	12.2
Stem				1660	1660				1.2	1.2				20.7	20.7
Root				1200	1200				1.4	1.4				16.8	16.8
		(Total)			(3,196)							(Total)			(49.7)
C. siamea															
Leaf				6106	6106				2.6	2.6				158	158
Stem				19085	19085				0.55	0.55				105	105
Root				6530	6530				0.75	0.75				49.0	49.0
		(Total)			(31,721)							(Total)			(312)

In year 3, total dry matter produced by *G. sepium* trees pruned four times annually increased to 1,771 g tree^{-1}, whereas trees pruned twice per year weighed 2,854 g tree^{-1} and those unpruned had a mean dry weight of 3,196 g (Table IV). In the fourth year, the unpruned *Gliricidia* produced 6,986 g tree^{-1}, comprised mainly of roots and leaves (Table V).

TABLE V. DRY-MATTER YIELDS, N CONCENTRATION AND TOTAL-N YIELDS OF PLANT COMPONENT PARTS. YEAR 4

Treatments	Dry matter					N concentration					Total N				
Species	Harvest no.					Harvest no.					Harvest no.				
Component	1	2	3	4	Total	1	2	3	4	Mean	1	2	3	4	Total
	(g tree^{-1})					(%)					(g tree^{-1})				
4 cuts per yr															
G. sepium															
Leaf	130	103	54	41	328	4.1	4.2	4.1	4.7	4.2	5.36	4.32	2.23	1.91	13.8
Stem	201		29	21	251	1.2		1.3	2.1	1.3	2.70		0. 36	0.37	3.45
Root				864	864				1.5	1.5				13.2	13.2
		(Total)			(1,443)							(Total)			(30.5)
C. siamea															
Leaf	666	64	105	21	856	3.0	3.1	3.5	3.1	3.1	19.8	2.00	3.64	0.66	26.1
Stem	2004	56	13		2073	0.67		1.2	1.7	1.21	13.4		0.70	0.22	14.3
Root				2325	2325				0.55	0.55				12.8	12.8
		(Total)			(5,254)							(Total)			(53.2)
2 cuts per yr															
G. sepium															
Leaf		557		107	664		3.8		4.2	4.0		21.3		4.51	25.8
Stem		904		111	1015		1.2		1.4	1.3		11.0		1.58	12.6
Root				1018	1018				1.8	1.8				18.0	18.0
		(Total)			(2,697)							(Total)			(56.5)
C. siamea															
Leaf		1119		160	1279		3.2		2.9	3.1		36.3		4.64	40.9
Stem		4379		157	4536		0.77		0.98	0.78		33.7		1.54	35.3
Root				3121	3121				0.76	0.76				23.7	23.7
		(Total)			(8,936)							(Total)			(99.9)
1 cut per yr															
G. sepium															
Leaf				2997	2997				4.0	4.0				119	119
Stem				673	673				1.2	1.2				8.0	8.0
Root				3316	3316				1.9	1.9				64.3	64.3
		(Total)			(6,986)							(Total)			(191)
C. siamea															
Leaf				11298	11298				2.8	2.8				317	317
Stem				85929	85929				0.74	0.74				636	636
Root				19989	19989				0.75	0.75				150	150
		(Total)			(117,216)							(Total)			(1,103)

In year 1, *Cassia siamea* trees pruned four times showed almost the same dry weight as *G. sepium*, whereas unpruned trees produced much higher yields than *Gliricidia* (Table II). *Cassia* trees in year 2 also showed no increase in growth due to shading (Table III). In the third year, after the tall border-row trees had been felled, growth improved, with the highest increase occurring in the fourth year, with the stem constituting the bulk of the dry matter (Tables IV and V).

TABLE VI. ENRICHMENT IN ^{15}N OF PLANT COMPONENT PARTS AND N DERIVED FROM FIXATION. YEAR 1

Treatment	^{15}N enrichment				Ndfa				N fixed				
Species	Harvest no.				Harvest no.				Harvest no.				
Component	1	2	3	4	1	2	3	4	1	2	3	4	Total
	(atom % excess)				(%)				(g tree^{-1})				
4 cuts per yr													
G. sepium													
Leaf	1.028	0.425	0.195	0.112	nf[a]	nf	14	39			0.44	3.34	3.78
Stem	1.141	0.425	0.206	0.345	nf	nf	17	23			0.58	0.63	1.21
Root				0.491				6.1				0.52	0.52
											(Total)		(5.51)
C. siamea													
Leaf	0.685	0.347	0.228	0.185									
Stem	0.751	0.406	0.247	0.451									
Root				0.523									
LSD$_{0.05}$	0.496	0.120	0.061	0.123									
2 cuts per yr													
G. sepium													
Leaf		0.519		0.133		1.4		38		0.17		1.71	1.88
Stem		0.674		0.351		nf		11				0.68	0.68
Root				0.604				nf					
											(Total)		(2.56)
C. siamea													
Leaf		0.430		0.215									
Root		0.503		0.393									
Stem				0.364									
LSD$_{0.05}$		0.114		0.116									
1 cut per yr													
G. sepium													
Leaf				0.132				nf					
Stem				0.254				nf					
Root				0.709				nf					
C. siamea													
Leaf				0.101									
Stem				0.156									
Root				0.204									

---

[a] No fixation, *Cassia* enrichment < *Gliricidia*.

The N concentrations of the leaves of *Gliricidia* were consistently higher than those of the stem or root, and higher than the leaves, stem and root of *Cassia* for all treatments and years of growth (Tables II-V).

Most of the N accumulated in *Gliricidia* and *Cassia* at the end of the first year was in the leaves, for all treatments (Table II). At the end of year 2, all treatments resulted in decreases in N assimilation (Tables II and III), whereas, in year 3, all treatments, except pruned four times, showed increases in total N from year 2 (Tables III and IV). Between years 3 and 4, *G. sepium* pruned twice and four times resulted in decreases in N accumulation (Table IV and V).

3.1.2. ^{15}N *enrichment and* N_2 *fixation*

In year 1, the ^{15}N enrichments in *G. sepium* pruned four times per year were higher, in the first 2 cuts, than those of the reference trees, therefore no fixation of N was measurable (Table VI). The third and fourth cuts showed lower ^{15}N enrichment levels compared to *C. siamea*. A total of 5.5 g N tree^{-1}, 13% of total N accumulated, was calculated to be fixed by *Gliricidia* pruned four times, at the end of the first year. The trees pruned twice fixed 2.6 g N tree^{-1}, which was equivalent to 8.1% of the total N accumulated in the first year. No fixation was detectable in unpruned *Gliricidia* trees in year 1.

In year 2, *G. sepium* in all treatments had lower ^{15}N enrichments than *C. siamea*, indicating that fixation contributed significant N (Table VII). Trees pruned four times per year had fixation of 2.9 g N tree^{-1} (26% Ndfa). In unpruned *Gliricidia*, only the roots showed N increases from year 1 and of this, 50% was calculated to come from N_2 fixation, equivalent to 1.7 g N tree^{-1}. The Ndfa values in kg ha^{-1} were determined on the basis of N accumulation for each year. Therefore in year 2, since no increases in total N were observed for unpruned trees or those pruned twice per year, fixation could not be calculated.

At the end of year 3, most treatments showed N increases from year 2, with N_2 fixation contributing up to 50% of total N (Table VIII). In year 4, %Ndfa was even up to 60% in trees pruned four times per year (Table IX).

3.2. *Gliricidia sepium* leaf decomposition

The original nutrient concentrations of the fresh leaves were: 4.2% N, 0.16% P, 2.6% K, 0.88% Ca, 0.31% Mg, 39% C, 2.3% polyphenol and 12% lignin. Therefore, the leaves had a C:N ratio of 9.3, and polyphenol+lignin:N ratio of 3.4.

3.2.1. *Dry matter and C loss*

A rapid rate of decomposition of leaf dry matter, 0.966 g day^{-1}, occurred within the first 10 days, resulting in a 56% loss (Fig. 2). The rate of decay became more gradual up to 40 days (>60% lost) and little change occurred thereafter.

A similar pattern was observed for loss of C (Fig. 3). In this case, the rate was faster than for dry matter. Nearly 40% of C was lost during the first 5 days and much of it, 75%, was released by the thirtieth day. Rainfall appeared to have little influence on rate of loss of dry matter or of C from this material.

3.2.2. *Nutrient release*

3.2.2.1. N, P and K

The releases of N, P and K were rapid during the first 10 days and slower thereafter (Figs. 4, 5 and 6). About 60% of the N was lost within 10 days (Fig. 4) and a total of 76% of the original N content of the leaves was released within the 70-day period. Releases of N and P were observed to be unrelated to that of C between (Figs. 7 and 8); initially the release of C was more rapid than of N or P, whereas between 10 and 30 days, the converse occurred.

TABLE VII. ENRICHMENT IN ^{15}N AND N DERIVED FROM FIXATION OF PLANT COMPONENT PARTS. YEAR 2

Treatment Species Component	^{15}N enrichment Harvest no.				Ndfa Harvest no.				N increase yr 2 Harvest no.				Ndfa Harvest no.				
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	Total
	(atom % excess)				(%)				(g tree^{-1})				(g tree^{-1})				
4 cuts per yr																	
G. sepium																	
Leaf	0.414	0.239	0.140	0.077	31	15	9.1	nf[a]	5.8	2.0	1.0	1.4	1.8	0.3	0.12		2.2
Stem	0.388	0.236	0.147	0.015	20	33	5.8	nf	0.17	2.0	0	0	0.03	0.7	nc[b]		0.71
Root				0.111				nf				0					
															(Total)		(2.91)
C. siamea																	
Leaf	0.601	0.280	0.154	0.073													
Stem	0.487	0.352	0.156	0.085													
Root				0.093													
2 cuts per yr																	
G. sepium																	
Leaf		0.378		0.065		2.1		54		0		0		nc		nc	
Stem		0.292		0.073		42		53		0		0		nc		nc	
Root				0.116				45		0		0				nc	
C. siamea																	
Leaf		0.473		0.142													
Stem		0.501		0.157													
Root				0.210													
1 cut per yr																	
G. sepium																	
Leaf				0.081				50				0				nc	
Stem				0.218				25				0				nc	
Root				0.136				50				3.38				1.67	1.67
															(Total)		(1.67)
C. siamea																	
Leaf				0.163													
Stem				0.289													
Root				0.274													

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[a] No fixation, *Cassia* enrichment < *Gliricidia*.

[b] Fixation non-calculable because N did not increase.

TABLE VIII. ENRICHMENT IN ^{15}N, N DERIVED FROM FIXATION, AND N INCREASE OF PLANT COMPONENT PARTS. YEAR 3

Treatments	^{15}N enrichment				Ndfa				N increase yr 3					Ndfa				
Species	Harvest no.				Harvest no.				Harvest no.					Harvest no.				
Component	1	2	3	4	1	2	3	4	1	2	3	4	Total	1	2	3	4	Total
	(atom % excess)				(%)				(g tree^{-1})					(g tree^{-1})				
4 cuts per yr																		
G. sepium																		
Leaf	0.414	0.150	0.102	0.086	31	30	28	22			1.2	4.0	5.2			0. 34	0.90	1.24
Stem	0.388	0.213	0.127	0.105	2	18	26	nf[a]	0.06		0.7	1.5	2.3	0.01		0.19		0.20
Root				0.066				13				4.5	4.5				0.59	0.59
																(Total)		(2.03)
C. siamea																		
Leaf	0.601	0.213	0.142	0.110														
Stem	0.487	0.259	0.170	0.099														
Root				0.191														
2 cuts per yr																		
G. sepium																		
Leaf		0.105		0.087		50		nf		0.9		25.8	26.6		0.45			0.45
Stem		0.182		0.091		43		13		1.5		1.0	2.5		0.64		0.13	0.77
Root				0.176				43				0	0				nc[b]	
																(Total)		(1.22)
C. siamea																		
Leaf		0.212		0.083														
Stem		0.319		0.105														
Root				0.308														
1 cut per yr																		
G. sepium																		
Leaf				0.049				50				10.6	10.6				5.31	5.31
Stem				0.066				25				19.9	19.9				4.90	4.90
Root				0.128				nf				10.9	10.9					
																(Total)		(10.2)
C. siamea																		
Leaf				0.056														
Stem				0.100														
Root				0.123														

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[a] No fixation, *Cassia* enrichment < *Gliricidia*.

[b] Fixation non-calculable because N did not increase.

TABLE IX. ENRICHMENT IN ^{15}N, N DERIVED FROM FIXATION, AND N INCREASE OF PLANT COMPONENT PARTS. YEAR 4

Treatment Species Cmpnt.	^{15}N enrichment Harvest no. 1	 2	 3	 4	Ndfa Harvest no. 1	 2	 3	 4	N increase yr 4 Harvest no. 1	 2	 3	 4	 Total	Ndfa Harvest no. 1	 2	 3	 4	 Total
	(atom % excess)				(%)				(g tree^{-1})					(kg ha^{-1})				
4 cuts/year																		
G. sepium																		
Leaf	0.381	0.226	0.077	0.070	20	29	61	62	0.58	0	0	0	0.58	0.11	nc[a]	nc	nc	0.11
Stem	0.260		0.123	0.087	43		16	0	0.51	0	0	0	0.51	0.22		nc		0.22
Root				0.159				21				6.05	6.05				1.29	1.29
															(Total)			(1.62)
C. siamea																		
Leaf	0.475	0.317	0.197	0.185														
Stem	0.459		0.147	0.087														
Root				0.202														
2 cuts/year																		
G. sepium																		
Leaf		0.265		0.085		9		14		16.5		0	16.5		1.53		nc	1.53
Stem		0.284		0.131		11		nf[b]		8.55		2.13	10.7		0.96			0.96
Root				0.260				nf				6.05	6.05					
															(Total)			(2.65)
C. siamea																		
Leaf		0.292		0.099														
Stem		0.320		0.110														
Root				0.161														
1 cut/year																		
G. sepium																		
Leaf				0.065				nf				0	0					
Stem				0.093				nf				0	0					
Root				0.212				nf				0	0					
C. siamea																		
Leaf				0.058														
Stem				0.074														
Root				0.135														

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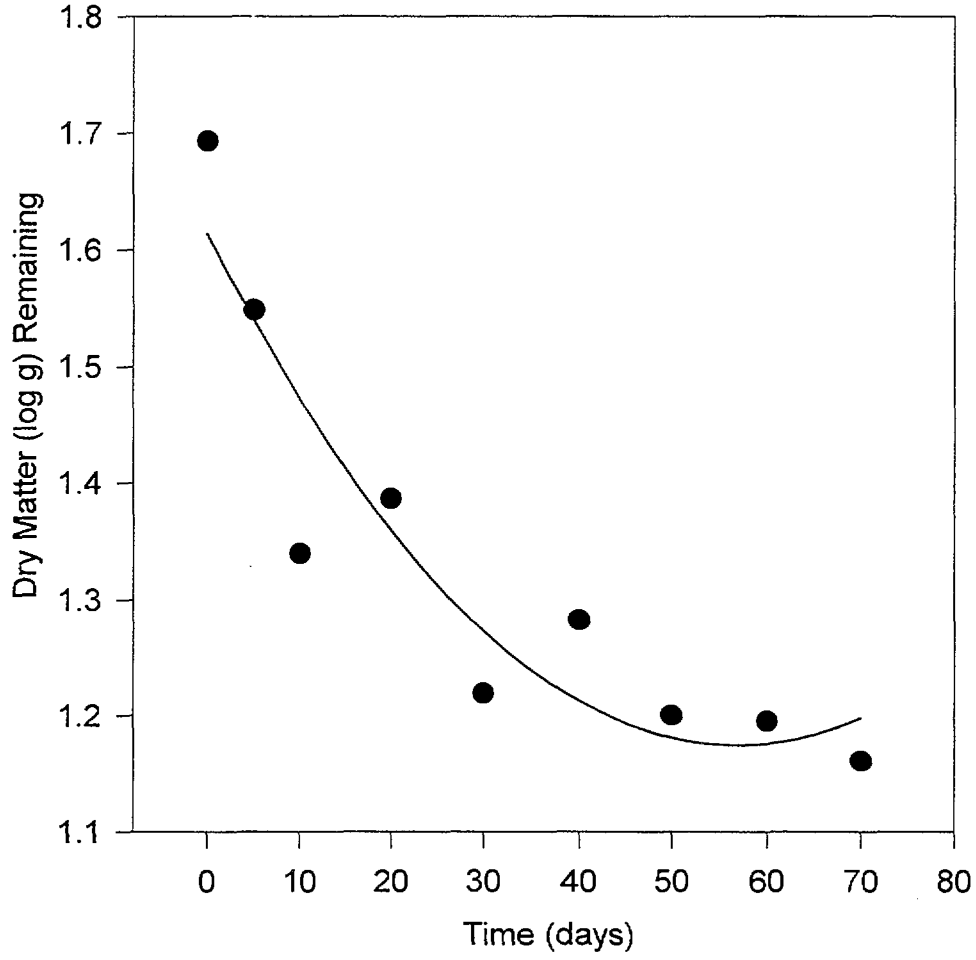
[a] Fixation non-calculable because N did not increase.

[b] No fixation, *Cassia* enrichment < *Gliricidia*.

Phosphorus showed a pattern of loss similar to that of N, albeit at a much reduced rate, with a half-life of 18 days (Fig. 5). About 35% was lost within the first 10 days and a total of 73% by 70 days (Fig. 5). Figure 8 shows a no-P-release phase between 10 and 40 days.



$y = 1.61 - 0.015x + 0.00014x^2$ ($r^2 = 0.96$)

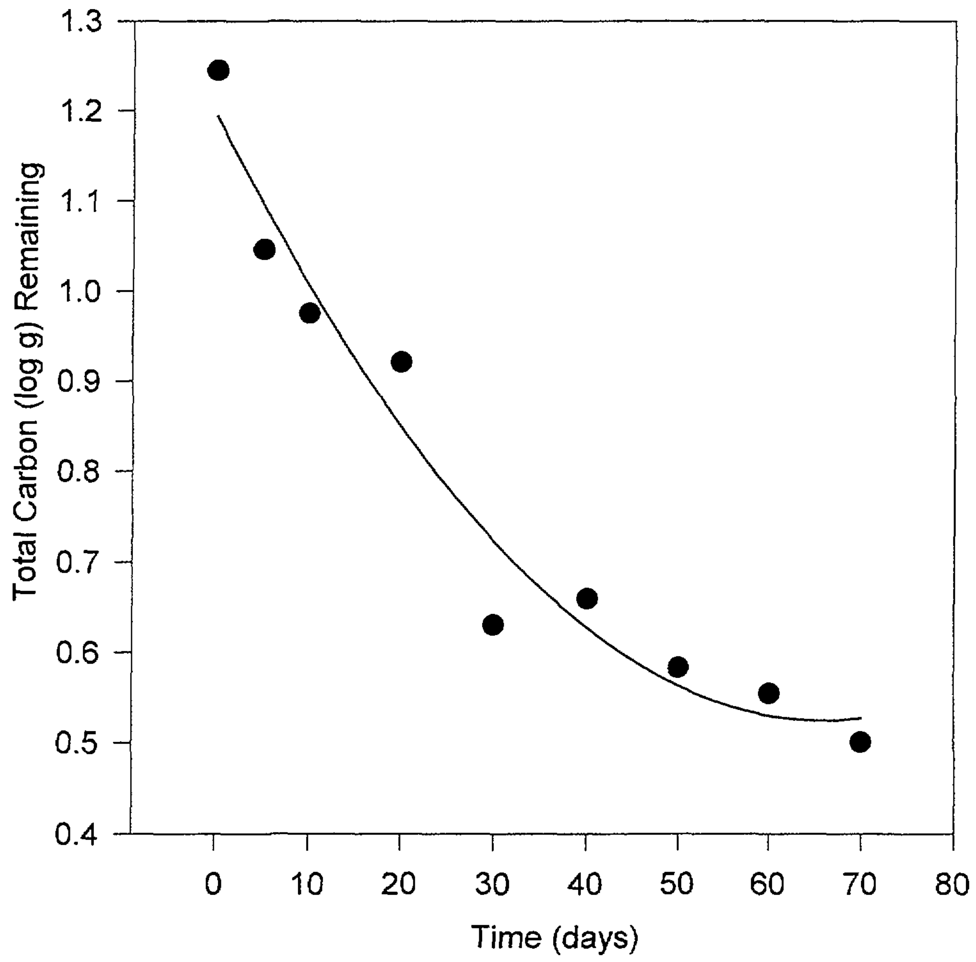
FIG. 2. Gliricidia sepium *leaf decomposition: dry matter loss.*

The rate of release of K was highest, with almost 90% gone within 10 days and 98% released by the thirtieth day. Little release occurred after 20 days of incubation. The half-life for K was 3 days (Fig. 6).

3.2.2.2. Ca and Mg

The pattern of release of Ca from the *G. sepia* leaves was similar to that of K, with about 85% lost within the first 5 days (Fig. 9). The half-life was calculated to be 1.1 days.

Loss of Mg closely followed that of C, with about 46% released within 5 days (Fig. 10). This high rate continued on to day 30 with a total of 86% being lost.



$$y = 1.194 - 0.020x + 0.00019x^2 \quad (r^2 = 0.96)$$

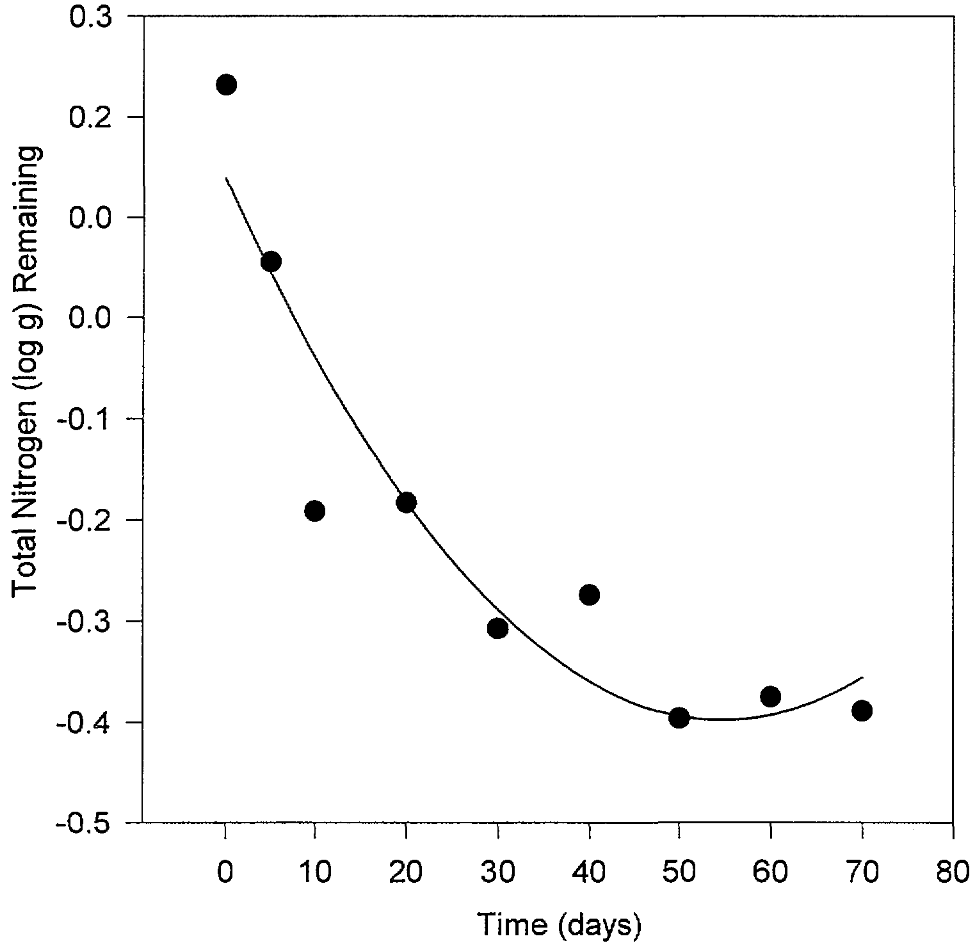
FIG. 3. Gliricidia sepium *leaf decomposition: C loss.*

3.3. Sweet corn alley-cropped with *Gliricidia sepium*

The treatments had significant effects on corn dry-matter yields and N uptake.

3.3.1. Dry-matter yields

In general, corn-stover yields increased from crop 1 to crop 3 except for the "root alone" and "root + hedgerow" treatments (Table X). The highest dry matter in crop 1 occurred in the "leaf + root" treatment, which was significantly higher than that of the control. However, no significant differences were observed between "root alone" and "leaf + root," irrespective of the presence or absence of hedgerow. Leaf prunings alone resulted in yields comparable to the control. There were similar trends in the second crop except that "leaf alone," and most of the other treatments resulted in dry-matter yields significantly higher than that of the control. The control plots of crop 3 produced plants of higher dry weight; and "control + hedgerow" gave a yield that was significantly higher than all others. The "root alone" and "root + hedgerow" treatments resulted in relatively low stover yields.



$y = 0.139 - 0.0196x + 0.00018x^2 \quad (r^2 = 0.89)$

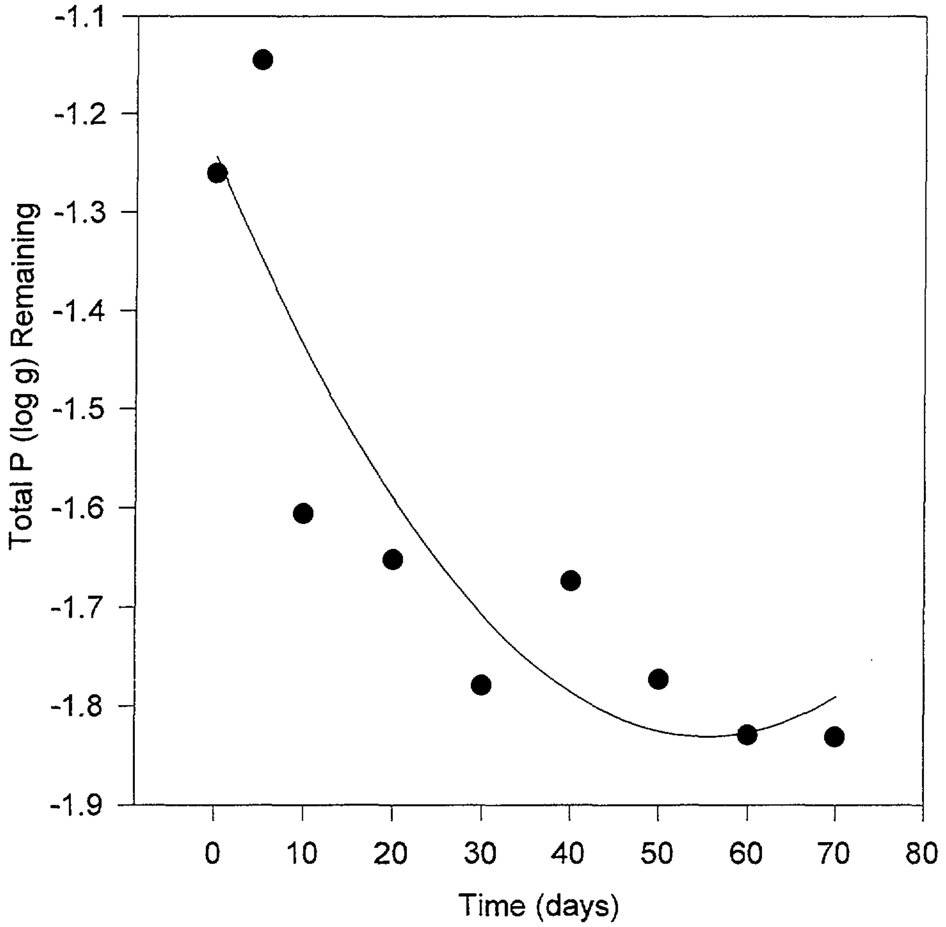
FIG. 4. Gliricidia sepium *leaf decomposition: N loss.*

Although no significant differences in ear yield were discerned among treatments, the trends in crop 2 corresponded with those for stover (Table XI). More-pronounced differences occurred in crop 3, again with trends similar to those for stover.

3.3.2. N concentration

In crop 1, the highest N concentration, obtained in corn stovers in the "leaf alone" treatment, was significantly greater than those produced by the other treatments (Table X). By contrast, in crop 2, the "leaf + root" combination with and without hedgerow resulted in the highest stover %N values; but, as with crop 1, the control and "root alone" treatment still resulted in relatively low N concentrations. Treatment effects in crop 3 were similar to those in crop 2 with values generally lower than those in crop 1.

The %N values for ears (Table XI) were generally higher than for stovers (Table X) for all treatments, with similar trends.



$y = -1.23 - 0.021x + 0.0019x^2$ ($r^2 = 0.81$)

FIG. 5. Gliricidia sepium *leaf decomposition: P loss.*

3.3.3. N uptake

In crop 1, "leaf + root" produced the highest accumulation of N in sweet-corn stover (Table X), although not significantly greater than with four other treatments; the lowest uptake value was obtained with the control treatment. The trends in crop 2 were similar, with "leaf + root + hedgerow" and "leaf + root" showing the highest values. In crop 3, leaf prunings alone and in combination with root or hedgerow resulted in significantly higher N uptake values than the control. The lowest N uptake was by "root alone" and "root + hedgerow." Nitrogen uptake values in plants generally increased from crop 1 to crop 3; however, "root alone" and "root + hedgerow" showed declining trends.

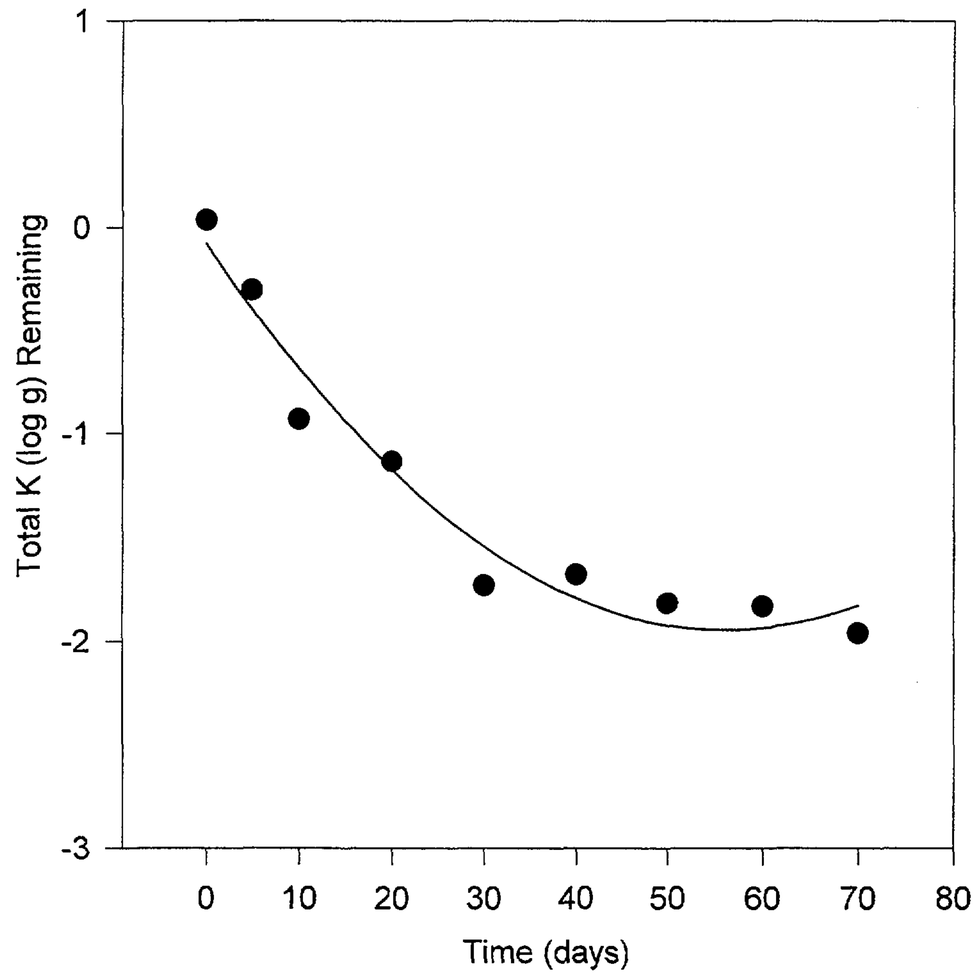
The N contents of the ears (Table XI) were generally lower than those of the corresponding stovers (Table X), but with similar trends of responses to the treatments for crops 2 and 3.

3.3.4. N derived from treatments

The highest contributions to stover N of corn crop 1, 63 and 57%, came from the "leaf alone" and "leaf + hedgerow" treatments, respectively." Trends in crop 2 differed slightly in that "leaf + root + hedgerow" made the highest contribution to N uptake, 39%, with "leaf + hedgerow," "leaf + root" and "leaf alone" treatments giving insignificantly different %NdfT values. As in crop 1, the lowest contributions were from the "root alone," "root + hedgerow" and "control + hedgerow" treatments. In crop 3, leaf prunings alone or in combination with roots or hedgerow made the highest contributions to N uptake (25-33%). Again, little N originated from roots. Trends in ear-N accumulation were generally similar to those for stovers in crops 2 and 3 although the values were lower (Table XIII). On the whole, the N derived from the prunings alone, or when combined with roots, in the presence or absence of hedgerow increased from crop 1 to 3. The contribution of the roots declined in crop 3.

3.3.5. Competition between hedgerow and crop

No significant differences in ^{32}P activity in hedgerow plants were observed from the point of application up to 4.2 m, with the "leaf + root" treatment or the control plots at 4 weeks after fertilizer application (WAF) (Table XIV). Where prunings were applied, highest activity was observed at 1.7 m from the ^{32}P micro-plot, insignificantly different from regrowths on trees at 2.2 m, but significantly higher than those at 3.2 and 4.2 m. However, there were no differences between the activities of regrowths at 2.2, 3.2 and 4.2 m from the point of application for all treatments. The situation remained unchanged at 6 WAF except that significant differences were observed in the "leaf + root" plot.



$y = -0.077 - 0.067x + 0.00595x^2 \quad (r^2 = 0.96)$

FIG. 6. Gliricidia sepium *leaf decomposition: K loss.*

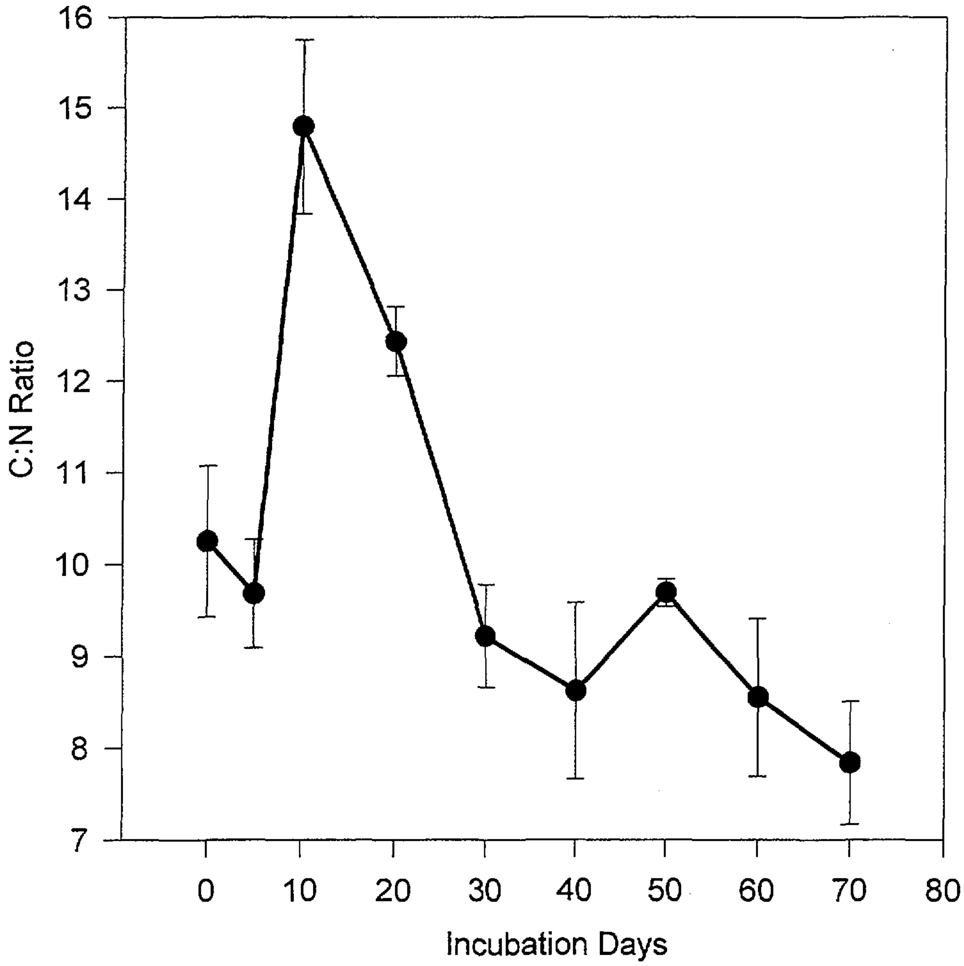


FIG. 7. Gliricidia sepium *leaf decomposition: C:N ratio.*

4. DISCUSSION

4.1. Nitrogen fixation by *G. sepium*

The ^{15}N enrichments of all plant parts showed descending trends from year to year, probably due to declines in the ^{15}N:^{14}N ratio in the soil [34]. The %Ndfa values ranged from 13 to 26 for trees pruned four times per year, 0 to 29 for trees pruned twice per year, and 0 to 50 for unpruned trees, indicating that field-grown *G. sepium* trees are not high N_2 fixers, even though others working with plants in pots and in concrete cylinders have reported otherwise [21,22]. Unpruned trees showed variable %Ndfa values, possibly due to growth-rates differences between fixing and reference trees. The roots of the reference trees may have explored more deeply than did those of *G. sepium*, resulting in lower ^{15}N-enrichment values.

Anomalous aspects of the data indicate difficulties in working with trees, e.g. %Ndfa values in excess of 50% were obtained with plants that apparently did not accumulate N, precluding the calculation of fixed N (Table VII). Large tree-to-tree variation in vigour is contributory.

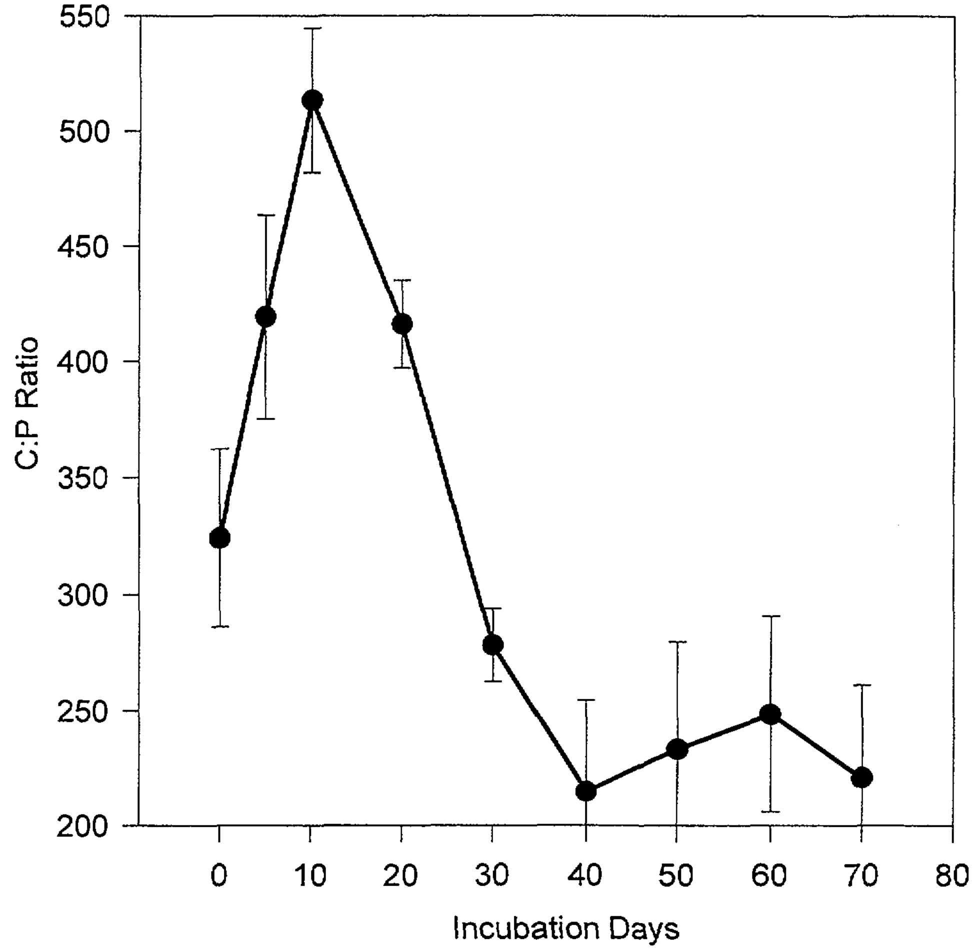
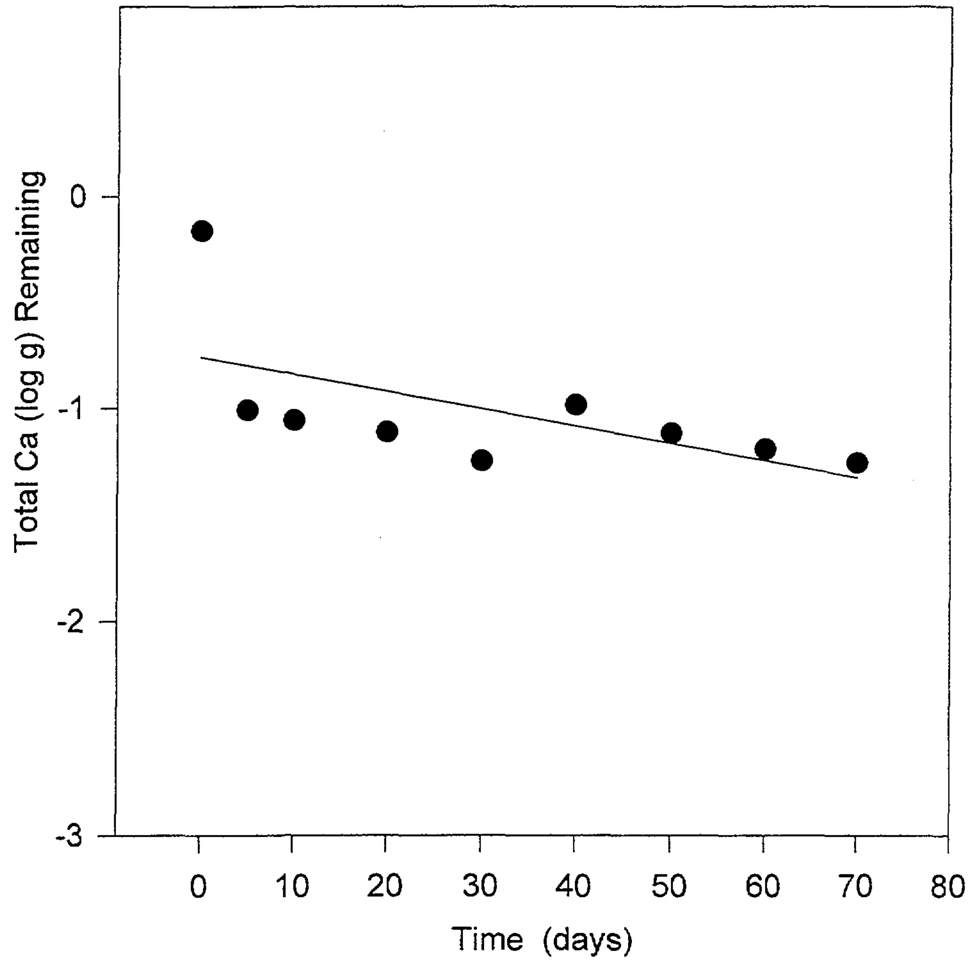


FIG. 8. Gliricidia sepium *leaf decomposition: C:P ratio.*

4.2. *Gliricidia sepium* leaf decomposition

Nutrient concentration, quality, soil biotic and environmental factors influence decomposition rates and patterns of nutrient release from plant materials [14,17,28,35]. The fast decomposition rate of the *G. sepium* leaves is attributable to relatively higher nutrient concentrations (see 3.2.) [35].

Initially rapid release of nutrients and C followed by a much-reduced rates is consistent with an initial leaching phase in the decomposition process [12,36,37]. The relatively slower rate of release of nutrients after the leaching phase could be due to relative increases in recalcitrant fractions, indicating dominance of soil fauna [27]. After the initial leaching phase for N, there was an accumulation or no-release stage followed by another release phase. Increases in C:N and C:P ratios (Figs. 7 and 8) indicate higher rates of release of N and P relative to C, possibly due to high proportions of N and P in soluble fractions.

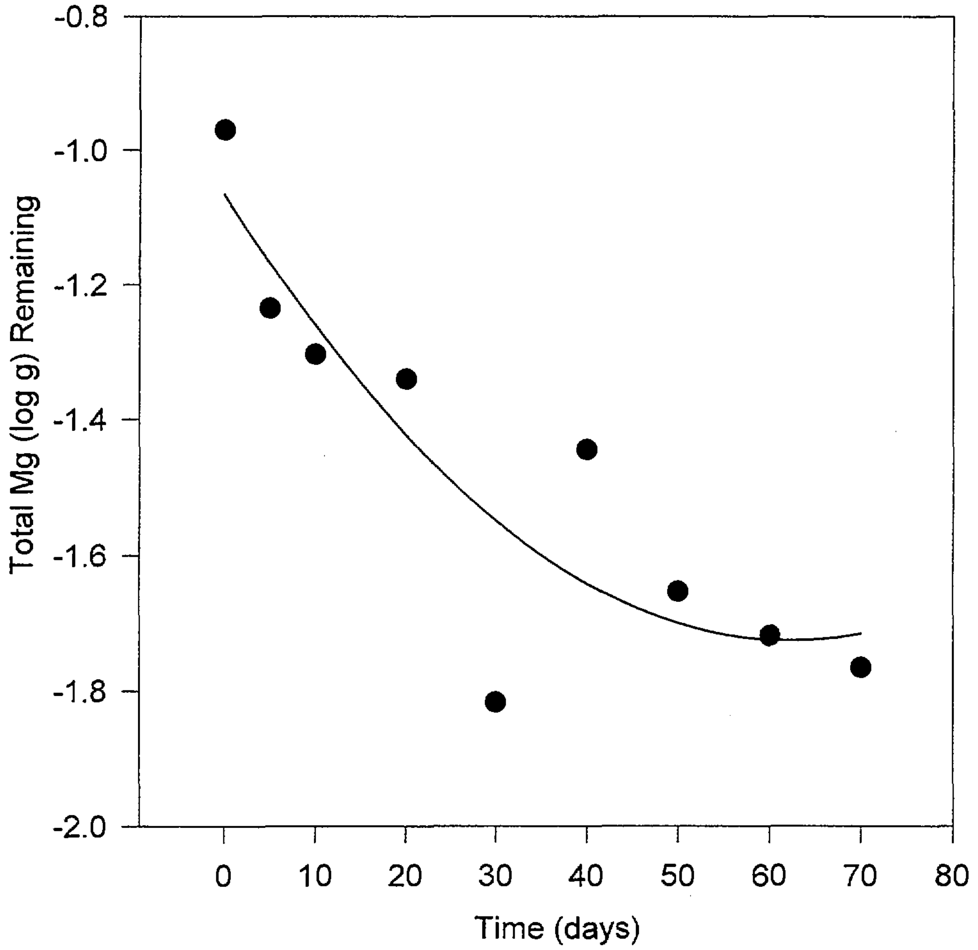


$$y = -0.758 - 0.0082x \quad (r^2 = 0.37)$$

FIG. 9. Gliricidia sepium *leaf decomposition: Ca loss.*

The rapid early loss of K indicates that leaching is the dominant mode of its release. Similar observations have been reported before [12,14,35], attributable to high mobility of K and Ca. The rapid leaching rates of Ca and Mg are also consistent with previous observations [11,38]. Apparently, leaching proceeds until a critical minimum concentration is reached. Our data have important implications for synchronizing nutrient release with crop-nutrient needs in low-input cropping systems. As such, split applications of fresh organic inputs may be the most efficient management option.

The fact that no pronounced changes occurred in the rate of nutrient release with precipitation (see Fig. 1) suggests that the influence of the latter is minimal above a threshold level that affects fauna activity [17]. Frequency of rainfall should be considered when establishing suitable nutrient-management systems in the humid tropics to ensure that necessary minimum soil-moisture content is achieved.



$y = -1.066 - 0.021x + 0.00017x^2 \quad (r^2 = 0.79)$

FIG 10. Gliricidia sepium *leaf decomposition: Mg loss.*

4.3. Sweet corn alley-cropped with *Gliricidia sepium*

The importance of leguminous green manures in maintaining soil fertility and crop productivity has been widely reported [8,16,19,39,40]. In view of the rapid decomposition of *G sepium* leaves, increases in growth and yields of the corn were attributable to the release of nutrients from the decomposing leaf prunings. In contrast, roots are generally believed to decompose at a slower rate. Although the results from our root-litter decomposition studies are contradictory, the longer response times may be due to high lignin content. In addition to this, the onset of the process itself could be delayed as a result of slower root-cell desiccation and mortality in the relatively moist environment of the sub-soil. The mixture of roots and leaves is expected to have a decomposition rate between the two extremes due to initial immobilization of nutrients released by the leaves.

The situation in crop 1 was such that the nutrients from prunings could not have been available at the time of crop demand. Most of the N could have been lost before optimum corn-root development occurred. Also, nutrient availability and uptake could have been severely limited by soil acidity and aluminium toxicity, factors to which corn is sensitive, hence the application of lime for the second crop.

Nonetheless, initial N immobilization and subsequent release in the "leaf + root" treatment probably reduced the losses resulting in the relatively high dry-matter yield in this treatment in crop 1. Other workers reported low residue-N recovery by the first maize crop when alley-cropped with *Leucaena* [18,19], attributed to immobilization of N in the soil organic matter and uptake by the hedgerows [11,41,42].

The pronounced effect of the prunings in crop 3 may have been due to the nutrients being available in better synchrony with crop demand [12,13], considering that the period of greatest need for N in maize is between 30 and 60 days after planting [16,43]. Similarly, since the control plants were supplied with readily available nutrients in the form of synthetic fertilizers, they would be expected to perform better than with the treatments. The relative decline in yields in the presence of hedgerows is attributable to competition effects [44].

The leaf treatments resulted in higher soil mineral N levels (Table XV). Competition with hedgerow could have been masked by the high nutrient availability resulting from decomposition of leaves and roots [45]. It is apparent that the competition effect of the hedgerows became more pronounced in conditions of relatively low nutrient availability and with proximity (Tables XIV). For instance, a substantial competition effect was observed with "root + hedgerow." Leaf prunings, on the other hand, provide more nutrients at the time of crop demand thereby masking the effect of the hedgerows. The passages created by decaying roots could also improve soil structure for root development and so enhance the exploitation of soil moisture and nutrient resources.

In summary, our data show that although N_2 fixation is not high in *G. sepium,* its leaf prunings improved N uptake and yields in sweet corn much more than did the residual roots. Application of leaf prunings at 21 and 45 days after planting proved to be most beneficial to the crop – the importance of applying organic materials to provide nutrients at the time of crop demand was thus confirmed. There was evidence of competition from hedgerow plants for P applied to alley-cropped corn; further research is needed for quantification. The practical implication of the data as a whole is that there is no advantage of the cut-and-carry system over permanent hedgerows, provided that prunings are applied at the time of crop demand.

TABLE X. DRY-MATTER YIELDS, N CONCENTRATION AND TOTAL-N UPTAKE BY CORN STOVER, CROPS 1, 2 AND 3

Treatment	Dry matter			N concentration			Total N		
	Crop 1	Crop 2	Crop 3	Crop 1	Crop 2	Crop 3	Crop 1	Crop 2	Crop 3
	(kg ha^{-1})			(%)			(kg ha^{-1})		
Control	898d[a]	1751b	3284b	1.8bc	1.2bcd	1.1bc	15.8c	21.7c	36.4b
Leaf alone	1082cd	2783a	3049b	2.4a	1.3abc	1.5a	26.2bc	36.2bc	45.1a
Root alone	2175a-d	2628a	1849d	1.5c	1.2cd	0.94cd	31.8abc	31.8cd	17.4c
Leaf + Root	3158a	2745a	3288b	1.8bc	1.5a	1.5a	56.2a	40.1ab	48.7a
Cntrl+Hdgrw	1628cd	2401ab	4278a	1.8bc	1.1d	1.1b	28.5bc	26.9de	49.2a
Leaf+Hdgrw	2686ab	2713a	3410b	1.6bc	1.3abc	1.5a	43.2ab	35.5bc	52.5a
Root+Hdgrw	2421abc	2453ab	2413c	1.5c	1.4ab	0.93cd	35.3ab	35.5bc	22.4c
Lf+Rt+Hgrw	1836a-d	3154a	3586b	1.9b	1.5a	1.4a	35.4ab	46.4a	51.6a

[a] Means in the same column followed by the same letter are not significantly different ($P \leq 0.05$).

TABLE XI. DRY MATTER, %N AND TOTAL N OF CORN EARS, CROPS 2 AND 3

Treatment	Dry matter		N concentration		Total N	
	Crop 2	Crop3	Crop 2	Crop 3	Crop 2	Crop 3
	(kg ha^{-1})		(%)		(kg ha^{-1})	
Control	990a[a]	1084ab	1.7ab	1.8bc	16.8ab	19.19ab
Leaf alone	1092a	1234ab	1.8ab	2.1a	19.8ab	26.3a
Root alone	1085a	575c	1.8ab	2.0abc	19.2ab	11.3b
Leaf + Root	1278a	1193ab	1.6ab	2.0ab	21.1ab	24.5a
Cntrl+Hdgrw	993a	1546a	1.5b	1.8bc	15.3b	27.5a
Leaf+Hdgrw	1443a	1084ab	1.7 ab	1.8abc	25.0a	19.6ab
Root+Hdgrw	1237a	808bc	1.9a	1.7c	23.6a	13.4b
Lf+Rt+Hgrw	1034a	1488a	1.9a	1.9abc	19.7ab	27.8a

[a] Means in the same column followed by the same letter are not significantly different ($P \leq 0.05$).

TABLE XII. NITROGEN IN STOVERS DERIVED FROM THE TREATMENTS, CROPS 1, 2, 3

Treatment	NdfT			NdfT		
	Crop 1	Crop 2	Crop 3	Crop 1	Crop 2	Crop 3
	(%)			(kg ha^{-1})		
Control	0.0c[a]	0.0d	0.0b	0.00c	0.00d	0.00b
Leaf alone	63a	23ab	32a	6.06b	9.16abc	14.0a
Root alone	0.0c	26abc	6.3b	0.00c	7.76bcd	1.12b
Leaf + Root	26b	31abc	33a	6.30b	12.7ab	16.3a
Cntrl+Hedgerow	0.0c	10cd	10b	0.00c	2.52cd	4.66b
Leaf+Hedgerow	57a	34ab	25a	11.0a	11.4abc	13.3a
Root+Hedgerow	7.6bc	14cd	0.0b	1.37c	5.78bcd	0.00b
Lf+Rt+Hdgerow	24b	39a	30a	2.84 c	18.0a	60.7a

[a] Means in the same column followed by the same letter are not significantly different ($P \leq 0.05$).

TABLE XIII. NITROGEN IN EARS DERIVED FROM THE TREATMENTS, CROPS 2 AND 3

Treatment	NdfT		NdfT	
	Crop 2	Crop 3	Crop 2	Crop 3
	(%)		(kg ha^{-1})	
Control	0.0c[a]	0.0d	0.00c	0.00d
Leaf alone	24abc	36a	4.95abc	9.38a
Root alone	27ab	9.0cd	4.27abc	0.72cd
Leaf + Root	38a	27ab	8.55a	7.27ab
Cntrl+Hedgerow	10c	18bc	1.62bc	4.82bc
Leaf+Hedgerow	37a	23abc	8.71a	4.57bcd
Root+Hedgerow	15bc	0.92d	4.27abc	0.17d
Lf+Rt+Hdgerow	37a	37a	6.96ab	10.26 a

[a] Means in the same column followed by the same letter are not significantly different at ($P \leq 0.05$).

TABLE XIV. ^{32}P ACTIVITY IN *GLIRICIDIA SEPIUM* REGROWTH WITH DISTANCE FROM POINT OF APPLICATION AT 4 AND 6 WEEKS AFTER ^{32}P APPLICATION

Time Treatment	^{32}P activity at distance from point of application 1.7 m	 2.2 m	 3.2 m	 4.2 m
	($\log_{10}$ ^{32}P activity)			
4 weeks				
Control + Hedgerow	2.886abc[a]	2.957abc	2.798abc	2.688abc
Leaf + Hedgerow	3.065a	2.766abc	2.521c	2.529bc
Root + Hedgerow	3.039ab	2.879abc	2.60abc	2.503c
Lf + Rt + Hedgerow	2.947abc	2.740abc	2.531bc	2.517c
6 weeks				
Control + Hedgerow	2.679abcd	2.537bcd	2.425d	2.571abcd
Leaf + Hedgerow	2.791ab	2.468d	2.463d	2.475cd
Root + Hedgerow	2.765abc	2.610abcd	2.477cd	2.484cd
Lf + Rt + Hedgerow	2.832a	2.509bcd	2.510bcd	2.502bcd

[a] Numbers followed by the same letter are not significantly different ($P \leq 0.05$).

TABLE XV. MINERAL-N STATUS OF TREATMENT PLOTS PRIOR TO ESTABLISHMENT OF CROP 3

Treatment	Mineral N ($mg\ kg^{-1}$)
Control	8.91c[a]
Leaf alone	24.6abc
Root alone	16.1bc
Leaf + Root	14.3bc
Control + Hedgerow	11.5c
Leaf + Hedgerow	31.3ab
Root + Hedgerow	14.0bc
Leaf + Root + Hedgerow	34.8a

[a] Numbers followed by the same letter are not significantly different ($P \leq 0.05$).

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