Chapter 4

Influence of time of application on the performance of gliricidia prunings as a source of N for maize

Abstract

Asynchrony between nitrogen (N) released by organic materials and N demand by the crop leads to low N use efficiency, which may undermine the success of legume tree prunings as a source of N. Synchrony of N release by organic materials and demand by crop may be achieved by optimizing time of application.

A field experiment was designed to determine the effects of time of application of gliricidia prunings and of addition of small doses of inorganic N fertilizer on N recovery and yield of maize. Six variations of application splits of gliricidia prunings (in October, December and February) were used, and as reference, six application rates of inorganic fertilizer N (0, 24, 48, 72, 96 and 120 kg N ha^{-1} all applied at once, 4 weeks after planting). Maize was grown from November 2001 to May 2002.

Higher N uptake and maize yield were obtained when gliricidia prunings were applied in October than when applied in December and February. Substitution values of 0.66, 0.32 and 0.20 were obtained for gliricidia prunings applied in October, December and February, respectively. Split application of prunings prolonged mineral N availability in the soil until March but did not increase N uptake and maize grain yield compared to sole application in October. Combinations of gliricidia prunings and inorganic fertilizer increased N uptake and maize yield over the prunings alone but the effect was additive only. We concluded that application of gliricidia prunings in October was more efficient than application in December and February.

4.1 Introduction

In agroforestry systems where tree prunings are used as source of nitrogen (N), recoveries of N range between 6 and 30% (Giller and Cadisch, 1995, Heal *et al*., 1997, Vanlauwe *et al*., 2001). The low N recovery by the associated crops is ascribed to asynchrony between the release of N by the organic materials and the demand of N by the crop, leading to high losses of N. Synchronizing release of N from the decomposing organic materials with the demand of N by the crop in agroforestry systems will reduce N losses and may lead to increased N-use efficiency of the applied organic materials (Swift, 1987; Myers *et al*., 1994). One of the 12 hypotheses proposed by the Tropical Soil Biology and Fertility (TSBF) for synchrony of nutrient release and nutrient demand by the crop states that the maximum crop yield achievable by the use of inorganic (mineral fertilizer) inputs can be approached by using organic materials when time of application, placement and quality of the organic materials are optimized (Myers *et al*., 1997). Mulongoy *et al*. (1993) examined the effect of time of pruning application on N uptake by maize, and found that organic materials applied between 2 weeks before and 2 weeks after planting of maize supplied more N than those applied at 4 and 6 weeks after planting. Mafongoya *et al*. (1997a) reported that application at the time of planting increased N uptake and yield. In Malawi the current recommendation is to apply tree prunings two weeks before planting. However, it is difficult to target at the recommended time of application because rain onset is very unpredictable.

Gliricidia prunings have phytotoxic effects on crops when fresh prunings are applied at the time of planting (Tian and Kang, 1994). The phytotoxins produced by gliricidia prunings during the first days of decomposition hinder the development of maize roots and also develop leaf chlorosis (see Chapter 3). In simultaneous intercropping of gliricidia with maize, pruning at two weeks after planting is not recommended because land preparation is difficult when the gliricidia trees have not been cut.

Considering the current knowledge that high crop yields have been achieved by multiple split application of inorganic N (*e.g.* Cassman *et al*., 1995), it could also be assumed that split application of high quality tree prunings may reduce N losses and increase N use efficiency by the crop. The prolific coppicing of gliricidia trees when they are repeatedly pruned offers an opportunity for repeated application of the prunings during the maize growing season. Earlier studies on time of pruning application have provided information on N recovery fractions but information is still lacking on (1) course of N release by organic materials applied at various times during the crop growing period and its relationship with N uptake, and (2) substitution values of the tree prunings when applied at different times.

We hypothesized that split application of organic materials during the growing season can prolong the availability of nutrients in the soil and may increase the nutrient-use efficiency by the crop. We set up a field experiment with the following objectives (1) to determine the effects of split application of gliricidia prunings on maize grain yield and N uptake, (2) to assess the substitution values of gliricidia prunings applied at various times during the year, (3) to examine the interaction between inorganic N fertilizer and gliricidia prunings, and (4) to monitor soil mineral N in the topsoil during the course of maize growth.

4.2 Materials and Methods

The experiment discussed in this chapter was coded MZ 18; the soil characteristics of the experimental field are described in Table 2.1. Sulphur (S) deficiency, which possibly could interfere, was not a problem at our site because in the past single super phosphate had been applied, which contains a substantial amount of S. The experiment was conducted in 2001-02 season. In this field experiment, gliricidia prunings were transferred from tree plots and applied in non-tree plots (see Section 2.2.3. for full methodology and below for some details).

4.2.1 Experimental treatments

The treatments comprised six rates of inorganic N fertilizer (0, 24, 48, 72, 96 and 120 kg N ha^{-1}) and six combinations of times of application of gliricidia prunings at a total rate of 3 tons ha^{-1}, or 87 kg N ha^{-1}. The gliricidia treatments were: (1) all gliricidia prunings applied at once in October (O), (2) one half applied in October and the other half in December (OD), (3) one half in October and the other half in February (OF), (4) one half in December and the other half in February (DF), (5) one third in October, one third in December and one third in February (ODF), and (6) one third in October, two thirds in December, one third in February (OD2F). Note that total application rate was 4 ton ha^{-1} in treatment OD2F.

Calcium ammonium nitrate (CAN) was used as the reference inorganic N fertilizer. The first three N fertilizer rates were combined in a factorial with the gliricidia prunings and the higher three rates represent additional inorganic N fertilizer treatments. The higher three rates of inorganic N fertilizer can also be considered as a factorial combination of 72 kg N ha^{-1} with the lower three rates (0, 24 and 48 kg N ha^{-1}). Therefore, this treatment will be referred to as CAN-72 in the text. Splitting the fertilizer treatments in this way resulted in a 8*3 factorial design, convenient for statistical analysis. The experiment was arranged in a randomized complete block design replicated three times. The gross plot size was 7.2 x 6.75 m with 9 ridges and 8 maize planting hills per ridge. Data was collected from the interior net plot of 3.60 x 3.75 m with 5 ridges and 4 maize planting hills per ridge.

Hybrid maize, NSCM 41, was the test crop. Maize was planted on 19th November 2001 and harvested in the first week of May 2002. CAN was applied in a single dose on 15th December 2001, and placed in small holes, 3 cm deep and about 6 cm away from the maize plants on the ridge. Gliricidia prunings were applied either at once or split. The times of application of October, December and February were chosen taking into consideration (1) the normal time for land preparation for the following cropping season, and (2) coincidence of two cutting times and two weeding times (Makumba and Maghembe, 1999) (refer to Section 2.2.1). Hence, these times of applications are in line with the normal field activities of smallholder farmers in Malawi. Each time gliricidia prunings were applied while green. At the first application, on 23rd October 2001, gliricidia prunings were laid in the furrows and a new ridge was made burying the biomass. At the subsequent applications (22nd December and 22nd February) gliricidia prunings were arranged on top of the ridge and were incorporated immediately, during weeding. Dates of application of gliricidia prunings and inorganic N fertilizer, together with rainfall are shown in Fig. 4.1.

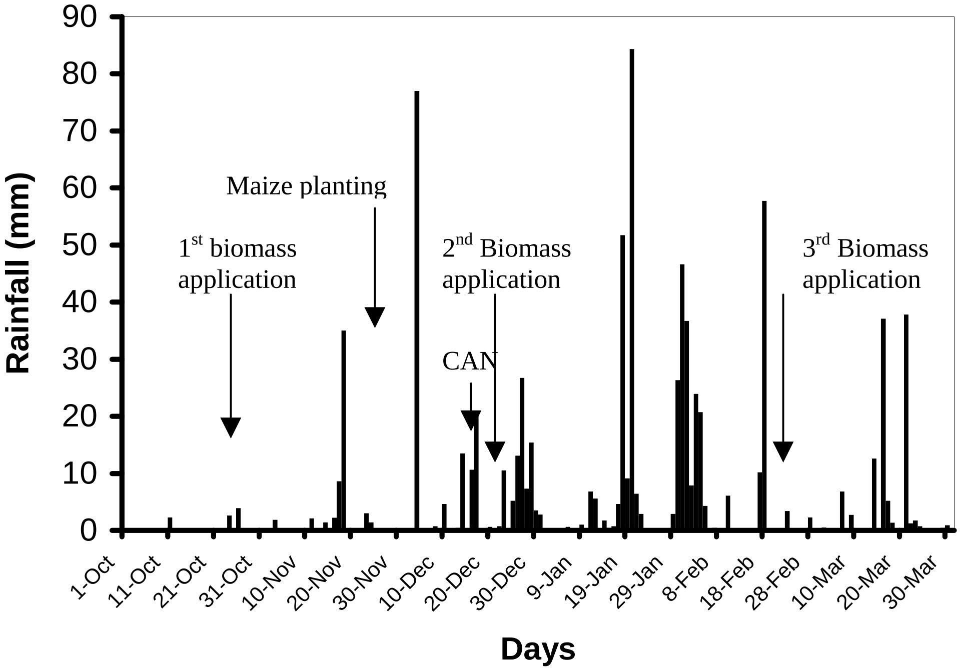

Fig. 4.1. Dates of biomass and CAN application, of planting of maize, and daily rainfall distribution between October and March [total rainfall (Oct-Mar) = 800 mm]

4.2.2 Soil mineral N determination

We assessed N release by gliricidia prunings applied at various times by regular sampling of the surface soil and analysis of soil mineral N. Soil samples were collected from the surface soil layer, 0-20 cm deep. Mineral N was determined in 2 M KCl soil extracts (Section 2.3).

4.2.3 Substitution values

The response of maize to gliricidia N was compared with the response to inorganic N fertilizer (CAN) with the method of "horizontal comparison" (Fig. 4.2). Via the response curve to CAN, the amount of CAN-N required to get the same Delta N uptake for gliricidia treatment was read. The ratio of that amount of CAN-N to the amount of applied gliricidia N is called the substitution value (SV). It is equivalent to the ratio of the recovery fractions of gliricidia N and CAN-N.

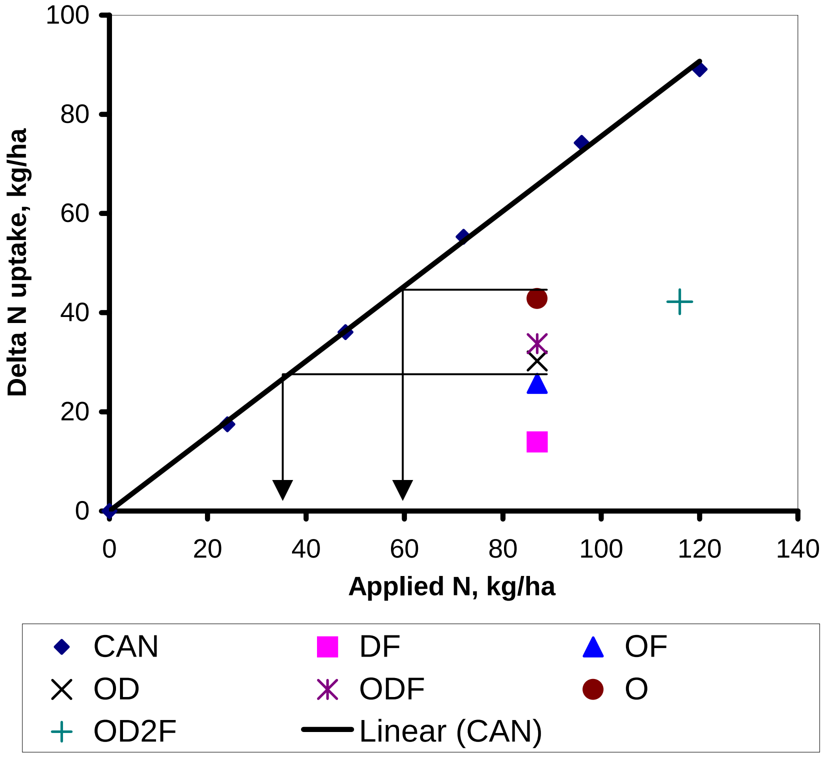

Figure 4.2. Relationship between Delta N uptake by maize and CAN application. The horizontal lines compare prunings and CAN at same level of N uptake (for the sake of legibility only two lines are shown). Codes as explained in text.

Recovery fraction is the ratio of Delta N uptake to N applied. In case the response to CAN is linear, the recovery fraction of CAN-N (RF_i) is equal to the slope of the regression line. With RFs obtained, the substitution value (SV) was calculated as follows:

$$SV = RF_o/RF_i \qquad \text{Eq. 4.1}$$

The subscripts o and i stand for organic and inorganic N. The substitution values were then substituted into the following equation to calculate equivalent N fertilizer of the gliricidia prunings:

$$EF = SV * N_{A,o} \qquad \text{Eq. 4.2}$$

EF is the equivalent fertilizer rate, and N_A is the rate of N applied.

The RFs and SVs found for the six combinations of application times were subjected to multiple regression analysis to calculate the EFs and SVs for individual times of application.

4.3 Results

4.3.1 Mineral nitrogen in topsoil

Figure 4.3 (Appendix 4.1) depicts the variations of mineral N in the topsoil during the maize growing period following time of application of organic materials. Generally, addition of 24 and 48 kg per ha of CAN-N gave higher mineral N in the topsoil than gliricidia prunings alone but the increase was not big. Treatment CAN-72 was lower than any gliricidia treatment, except on 22 Dec for DF.

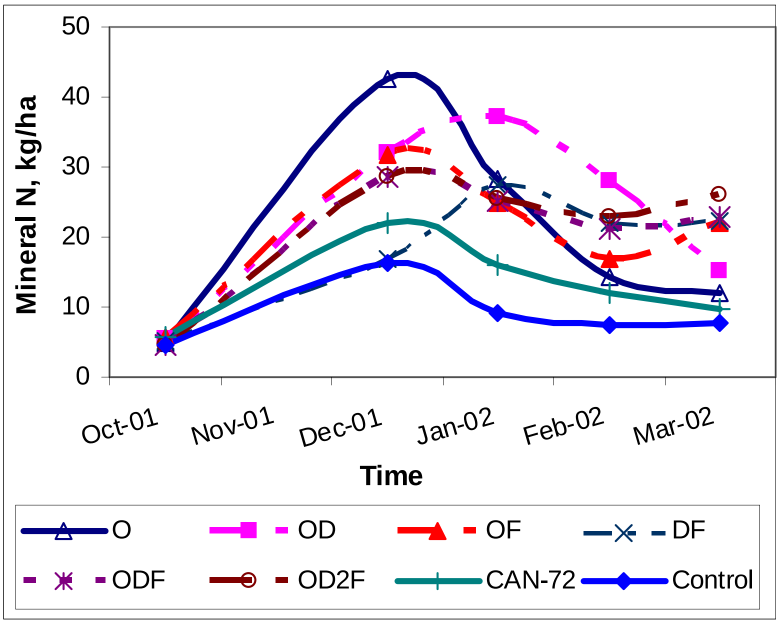

Fig. 4.3. Effect of gliricidia prunings applied at various times on mineral N present in the soil surface layer (0-20 cm) during the maize growing period. L.S.D's were: 0.042, 0.031, 0.023, 0.034, 0.035 [$\log_{10}$ (n + 1) transformed data (Gomez and Gomez, 1984)] for Oct, Dec, Jan, Feb and Mar respectively.

Table 4.1. Analysis of variance for maize grain yield and total dry-matter yield

Source of variation	d.f.	s.s.	m.s.	F	Sign. level[1]
Maize Grain					
Replicate	2	0.14	0.07	1.54	ns
Treatments	23	60.02	2.61	56.05	**
Time of application (T)[2]	7	35.39	5.06	108.60	**
Extra CAN (E)	2	23.50	11.75	252.40	**
T*E	14	1.13	0.08	1.73	ns
Error	46	2.14	0.05		
Total	71	62.31			
Dry-matter					
Replicate	2	0.25	0.13	1.57	ns
Treatments	23	227.88	9.91	122.40	**
Time of application (T)	7	132.17	18.88	233.26	**
Extra CAN (E)	2	94.21	47.10	581.88	**
T*E	14	1.50	0.11	1.33	ns
Error	46	3.72	0.08		
Total	71	231.86			

[1] **, * = Significant at 1% and 5% level respectively,
[2] including control and CAN-72

After application of all the prunings in October (Treatment O) mineral N in the topsoil increased up to 42 kg N ha^{-1} in December, but sharply declined in January (Fig. 4.3). Split application, OD, ODF and OD2F, increased mineral N in December, January and February. Late application DF resulted in low N in the topsoil early in the season. Treatment ODF maintained mineral N between 21 and 28 kg N ha^{-1} from December up to March.

4.3.2 Maize grain and dry-matter yield

The analysis of variance (Table 4.1) shows that gliricidia prunings and CAN significantly (P = 0.01) increased maize grain and dry-matter yields. The interaction between gliricidia prunings and inorganic fertilizer and the block effects were not significant for the two yield parameters. Maize responded significantly (P = 0.01) to CAN application; the grain yield continued to increase with increasing rates of CAN. Maize grain yield varied significantly (P = 0.01) with time of application of gliricidia prunings. It ranged between 1.7 and 2.3 tons ha^{-1} in treatments that received either all or at least a part of the gliricidia prunings in October (Table 4.2). Treatment DF yielded low, 1.3 tons ha^{-1}. Combining gliricidia prunings with 24 or 48 kg ha^{-1}

inorganic N fertilizer increased the mean grain yield by 0.8 and 1.4 t ha^{-1}, respectively, over the gliricidia prunings alone.

Total aboveground dry-matter yield was 4.9 t ha^{-1} in Treatment O and 2.7 t ha^{-1} in Treatment DF. The addition of 24 and 48 kg ha^{-1} of N from CAN increased the mean total dry-matter yield by 1.4 and 2.8 t ha^{-1} over the prunings alone.

Table 4.2. Grain yield and total dry-matter (grain + stover) yield (t ha^{-1}) of maize fertilized with CAN and/or gliricidia prunings (split) applied in October (O), December (D) and February (F).

CAN-N(kg ha^{-1})	0[a]	24	48	Mean
Maize grain yield (tons ha^{-1})				
Control	0.62 e	1.22 e	2.03 d	*1.29*
DF	1.29 d	1.51 e	2.30 d	*1.70*
OF	1.68 c	2.53 d	3.22 c	*2.48*
OD	2.01 bc	2.88 cd	3.46 bc	*2.78*
ODF	2.06 b	3.00 bc	3.34 c	*2.80*
O	2.23 b	3.06 bc	3.82 b	*3.04*
OD2F	2.30 b	3.29 b	3.51 bc	*3.03*
CAN-72	2.71 a	3.66 a	4.36 a	*3.58*
Mean	*1.86*	*2.64*	*3.26*	*2.59*
Total dry-matter yield (tons ha^{-1})				
Control	1.55 f	2.55 f	4.23 f	*2.77*
DF.	2.67 e	3.33 e	5.03 e	*3.67*
OF	3.41 d	4.87 d	6.48 d	*4.92*
OD	4.06 c	5.48 c	6.95 cd	*5.50*
ODF	4.18 c	5.56 c	6.93 cd	*5.56*
O	4.93 b	6.57 b	7.88 b	*6.46*
OD2F	4.65 b	6.30 b	7.40 c	*6.12*
CAN-72	5.62 a	7.22 a	8.60 a	*7.15*
Mean	*3.88*	*5.23*	*6.69*	*5.27*

[a]In a column means followed by the same letter are not significantly different at 5% level by DMRT.

4.3.3 N uptake by maize

CAN and time of prunings application significantly (P = 0.01) affected N uptake (Table 4.3). No interaction was found between CAN and gliricidia prunings. Table 4.4

Table 4.3. Analysis of variance table for the total N uptake by maize

Source of Variation	D.F.	S.S.	M.S.	F	Sign. Level[a]
Replication	2	0.42	0.21	<1	
Treatment	23	39914.36	1735.41	87.73	**
Time of application (T)[b]	7	21566.65	3080.95	155.75	**
Extra CAN (E)	2	17897.77	8948.89	452.38	**
T*E	14	449.94	32.14	1.62	ns
Error	46	909.96	19.78		
Total	71	40824.74			

[a] ** = Significant at 1% level, [b] including the control and CAN-72

Table 4.4. Nitrogen uptake by maize (grain and stover) fertilized with gliricidia prunings applied at various times during the season and/or with CAN.

	Nitrogen Uptake (kg ha^{-1})			
CAN-N (kg N ha^{-1})	0 [a]	24	48	Mean
Time of application				
Control	18.4 f	35.9 d	54.5 e	36.28
DF	32.3 e	42.7 d	65.9 d	46.95
OF	44.2 d	66.3 c	84.3 c	64.93
OD	48.7 cd	67.4 bc	94.2 b	70.10
ODF	52.1 c	81.2 b	94.1 b	75.82
O	61.3 b	81.3 b	101.4 ab	81.32
OD2F	60.6 b	82.0 b	98.6 b	80.40
CAN-72	73.7 a	92.7 a	107.5 a	91.29
Mean	*48.93*	*68.69*	*87.55*	*68.39*

[a]In a column means followed by the same letter are not significantly different at 5% level by DMRT.

presents total N uptake by maize crop, being the sum of N yield in the above-ground parts of the maize plant (stover, rachis and grain). Addition of 24 and 48 kg N ha^{-1} inorganic fertilizer increased average N uptake by 20 and 39 kg ha^{-1}, respectively. N uptake was lowest (32.3 kg N ha^{-1}) when gliricidia prunings alone were split applied in December and February (DF), and highest (61 kg N ha^{-1}) in Treatments O and OD2F.

4.3.4 N recovery fractions

Table 4.5 presents the recovery fractions and substitution values of gliricidia prunings for the various times of application. Recovery fractions of 16 and 49% were obtained

Table 4.5. Recovery fractions, substitution values and equivalent rates of fertilizer N for 87 kg N in gliricidia prunings, as affected by the time of application.

Time of application	RF	SV	EF
As derived from Table 4.4 and calculated with Eqs. 4.1 and 4.2			
DF	0.16	0.21	18
OF	0.30	0.40	35
OD	0.35	0.47	41
ODF	0.39	0.52	45
O	0.49	0.65	57
OD2F	0.36	0.48	56
CAN	0.75	-	-
By multiple linear regression analysis			
October	0.50	0.66	57
December	0.23	0.32	28
February	0.15	0.20	17

when prunings were applied in DF and O respectively, and varied between 30 and 39% for split applications with part of the prunings applied in October. Substitution values ranged from 0.21 (for DF) to 0.65 (for O), and those calculated for “unsplit” from 0.66 (in O) to 0.20 (in F). The equivalent rates of fertilizer N for 3 tons of pruning, or 87 kg org. N ha^{-1} application ranged between 57 to 17 kg N.

4.4 Discussion

4.4.1 Soil mineral N

Application of gliricidia prunings in October substantially increased mineral N in topsoil by December. Split application of prunings in October and December maintained the levels of mineral N high for a further period of 2 months compared to single application. Mineral N rapidly declined in Treatment O, probably as a result of uptake by the crop and leaching to depths below 20 cm. Ikerra *et al*. (1999) reported similar trends in a mixed intercropping of gliricidia with maize; they found a peak of mineral N in December and a sharp decrease of mineral N in January. Tian *et al*.

(1993), Mugendi *et al*. (1999) and Cobo *et al*. (2002) also found that mineral N declined 2-4 weeks after peak N mineralization.

4.4.2 N uptake

The early release of mineral N from the prunings applied in October might have been in synchrony with the N demand by maize, resulting in high N uptake and grain yield. The low N uptake and low maize yield in DF treatment suggests that N released late in the season was in asynchrony with the N demand by maize.

Increases of mineral N availability in the soil surface were prolonged over a longer period in Treatments OD and ODF than in Treatment O (Fig. 4.3). Nevertheless OD and ODF did not have higher maize grain yields and N uptake than Treatment O. With split application about half or a third of the organic N was applied at the beginning of the season. This resulted in less N being released early in the season than when all 87 kg N ha^{-1} was applied in October. The treatments with split application had more N remaining in the topsoil at the end of the growing season than the treatments receiving inorganic fertilizer alone (Fig. 4.3). The current crop might not have benefited from the mineral N available in the topsoil late in the season. Mafongoya *et al*, (1997a) suggested that the next crop might benefit from this residual N. In simultaneous cropping system as well as when maize is intercropped with late maturing crop (*e.g*. pigeon pea) the remaining N may be taken up by the trees or the crop still growing.

Maize N uptake is explained better by mineral N in the top 20 cm of soil in December than by soil mineral N in January and later, as revealed by the linear regression correlation coefficients of 0.73, 0.32, 0.29, 0.15 (Fig. 4.4). This finding is in conformity with the high correlations of maize grain yield with pre-season N reported by Barrios *et al*. (1998) and Ikerra *et al*. (1999). Combining gliricidia prunings with 24 and 48 kg N ha^{-1} of CAN improved R-square, especially for relationship between maize grain yield and soil mineral N sampled in January (Table 4.6). As CAN had been applied in December, this improvement is another indication that the presence of N early in the season was beneficial for maize growth

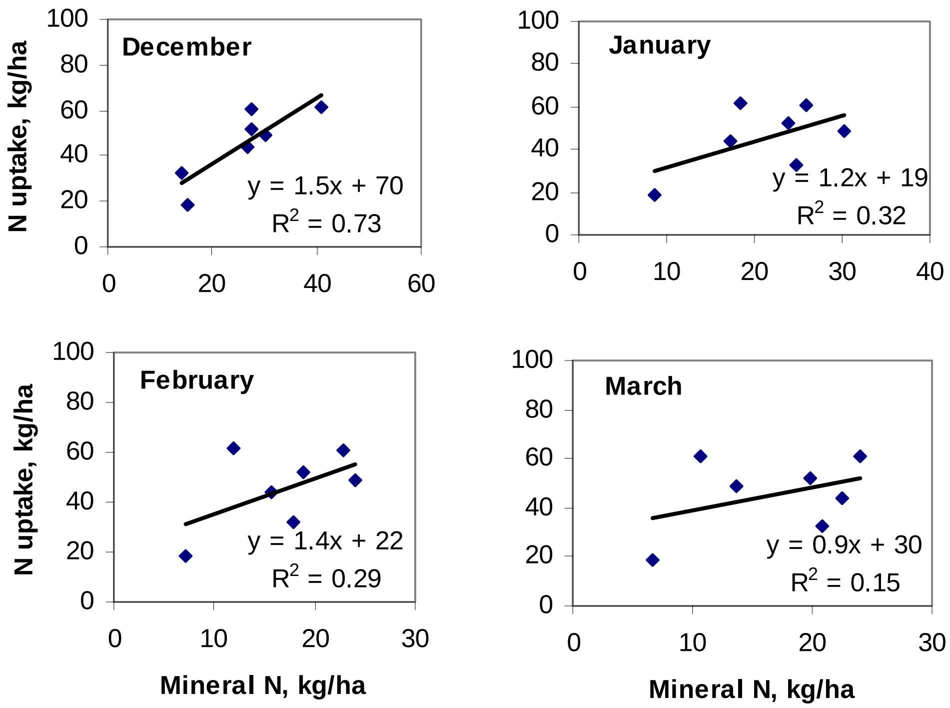

Fig 4.4. Relationship between maize N uptake and soil mineral N assessed at various times during the maize growing period.

Table 4.6. R-squares of the linear regression relating N uptake by maize and mineral N assessed in the topsoil, 0-20 cm, at various times during the growing season

Time of N assessment	Gliricidia alone	Gliricidia + 24 kg N ha^{-1}	Gliricidia + 48 kg N ha^{-1}	average
December	0.73	0.70	0.70	*0.71*
January	0.32	0.49	0.64	*0.48*
February	0.29	0.25	0.30	*0.28*
March	0.15	0.11	0.19	*0.15*
Average	*0.37*	*0.38*	*0.46*	

The high recovery fraction for CAN fertilizer (Table 4.5) points to excellent conditions for uptake which are ascribed to low and rather uniform distribution of the rainfall throughout the growing season (800 mm, Fig. 4.1) preventing leaching of N beyond the root zone of the maize (See Fig. 5.4). These excellent conditions also explain why in our experiment a recovery fraction of 0.49 was obtained when 3 t ha^{-1} gliricidia prunings were applied in October (about 4 weeks before planting), which is 1.8 times the recovery fraction of 0.27 reported by Mafongoya *et al*. (1997a) for *Calliandra calothyrsus* prunings applied at planting (46.5 kg N extra uptake by 5 t prunings with 3.83% N). Recovery fraction was highest when all prunings were applied in October, followed by split applications with at least the first application done in October. Quite often low N recoveries (less than 0.30) have been reported for gliricidia prunings under field conditions (Haggar *et al.*, 1993; Tian *et al*., 1993; Palm, 1995). Our study indicates that application of prunings 4 weeks before planting can increase the N recovery to 0.40-0.50.

4.4.3 Split application of gliricidia

In general split application of organic materials reduced the N recovery of N from the organic materials. Mafongoya *et al*. (1997a) also found that split application of calliandra prunings reduced N recovery fractions from 0.27 when applied at planting to 0.16 when split applied with 50% at planting and the other half at 2 weeks after planting, and to 0.12 when the other 50% of prunings was applied at 4 weeks after planting. Testing the effect of split application of cattle slurry and inorganic N fertilizer on maize silage production in the Netherlands, Schröder (1998) found that split application of cattle slurry reduced maize dry-matter yield in experiments that received low rainfall while yield was increased in experiments that were exposed to excess rainfall at the beginning of the season. Split application of inorganic N fertilizer had a small positive effect on the maize dry-matter yield. According to Schröder (1998) excessive rainfall at the beginning of the season favored a positive response to split application of inorganic fertilizer. In a synthesis of trials designed to find out optimum way of splitting applications of inorganic fertilizer in the humid tropics of Suriname, Boxman and Janssen (1990) concluded that split application of inorganic fertilizer into 2 or 3 portions at planting and 4 and 7 weeks after planting resulted in higher corn yields provided the first application was relatively high. The difference of the effects of split application of organic materials and inorganic fertilizer on corn yield could be explained by the fact that inorganic fertilizer N is in plant available form right from the time of application whereas for organic materials there is a time lag for organic N to be converted into available N through the process of mineralization. Also in split application, the portions applied later in the season have too little time for mineralization to meet with crop demand. As the mineralization of gliricidia-N was not affected by the time of application (Fig. 4.5) as long as there was sufficient moisture, late application means that a great part of mineralized N comes too late for plant uptake. Evidently, split application resulted in asynchrony. The effect of application time will be further discussed in Chapter 8.

The substitution value for gliricidia prunings applied in October (SV_O) was three times as high as that split applied in December and February (SV_{DF}). Substitution values for the applications in December and February were 0.32 and 0.20, respectively (Table 4.5). The substitution values translate into equivalents of 57, 28 and 17 kg N ha^{-1} from CAN fertilizer. Mulongoy *et al.* (1993) found that application of 8 t ha^{-1} gliricidia prunings at planting was equivalent to 70 kg N (Urea) ha^{-1}. This translates to a substitution value of 0.23, much lower than our results. Again we ascribe this to excellent conditions in season 2001-02 for N uptake.

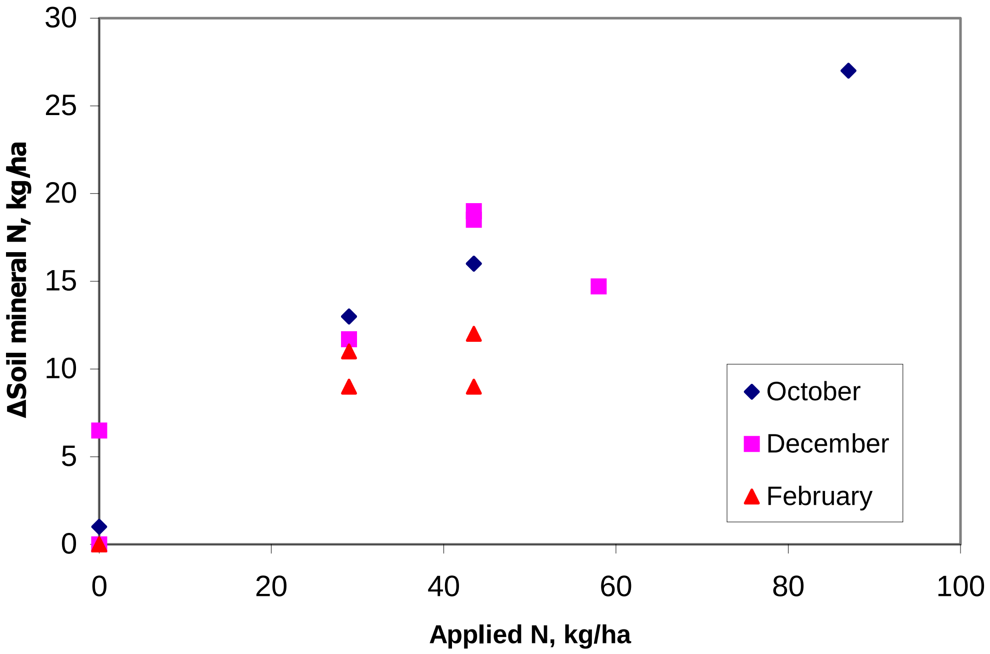

Fig. 4.5. Scatter plot of delta soil mineral N (0-20 cm), measured at about one to two months after application, and the amount of N applied with prunings, at different times of application.

4.4.4 Method of application

Generally, maize N uptake is higher when prunings are incorporated than when they are surface applied (Kaufusi and Asghar, 1990; Ezenwa and Alasiri, 1991; Mafongoya *et al*., 1997c). This could in part explain the high N recovery fractions obtained in this experiment, and low N recovery fractions in those experiments where the prunings are surface applied. Surface application of prunings before planting could expose the prunings to further drying hence loose their quality (Mafongoya *et al*., 1997b). This implies that the used method of application in our study, incorporation on the ridge thus concentrating the nutrients where most of the maize roots grew, probably also contributed to the relatively high N recovery in this study.

4.4.5 Additional effects of organic materials

To verify whether possible differences in maize yield were due only to N and not to additional effects of the organic materials, maize yield was plotted against N uptake, for the treatment with only CAN or gliricidia prunings (Fig. 4.6). The points for gliricidia are a little higher at N uptake below 60 kg ha^{-1}, but practically no additional benefit of organic materials is present. The ratios of yield to uptake, or internal utilization efficiencies (Section 1.8), are rather low, around 40 kg grain per kg N taken up, compared to a maximum for maize of 70 kg ha^{-1} (Janssen *et al.*, 1990). This indicates that growth conditions were not optimal, probably too dry, and that organic materials could not improve the conditions. So the same conditions were optimum for uptake efficiency, but not for internal utilization efficiency.

In Fig. 4.7 showing the relations between N uptake and fertilizer N applied, the regression lines of the combinations of gliricidia prunings and inorganic N run almost parallel to the regression lines of the control and CAN-72, indicating that combinations of inorganic N fertilizer and gliricidia prunings had similar effects on N uptake as inorganic N alone. Also this demonstrates that organic and inorganic N sources had only additional and no interaction effects, as was shown also by the analysis of variance (Tables 4.1 and 4.3).

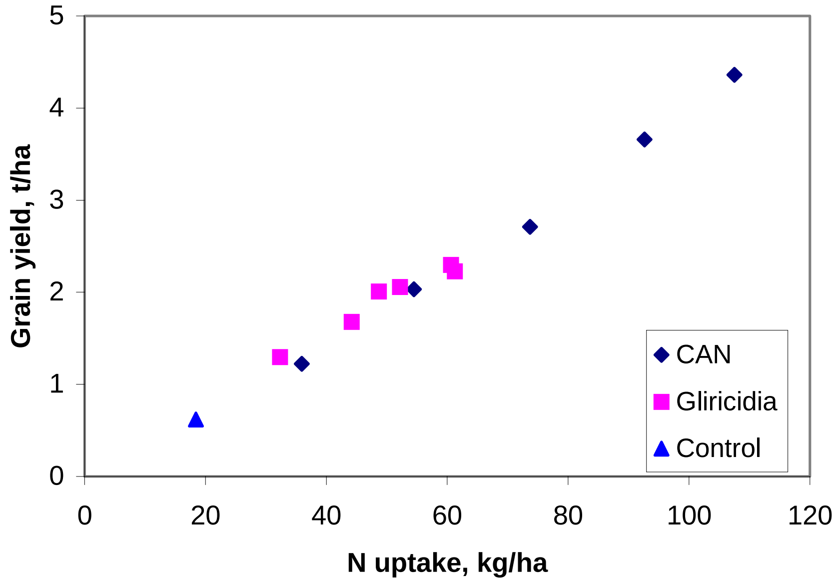

Fig. 4.6. The relationship of maize grain yield and N uptake, for tree prunings and CAN. The slope of the lines represents internal N-utilization efficiency.

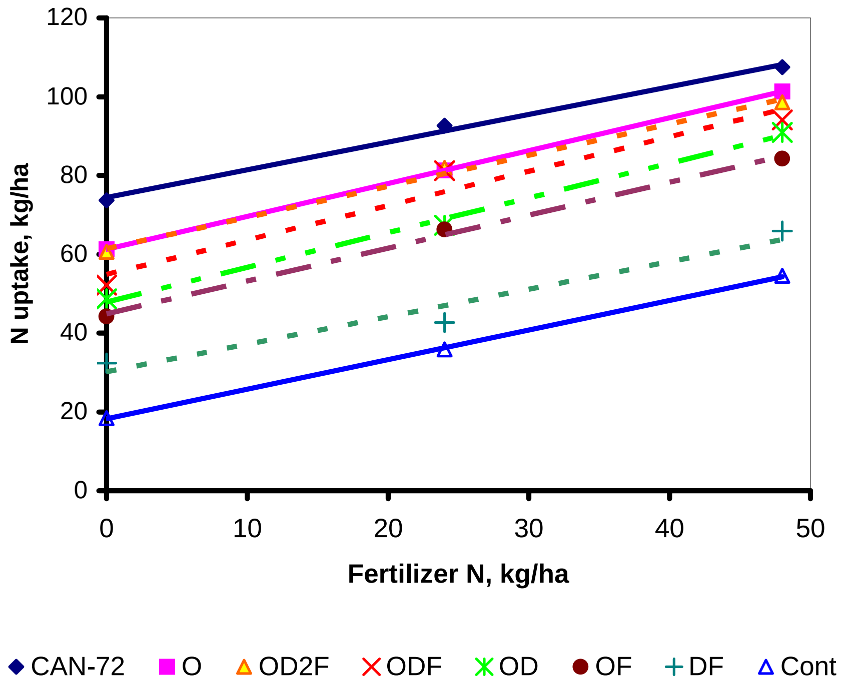

Fig. 4.7. N uptake in relation to applied equivalent fertilizer N.

4.5 Conclusions

The results from this study clearly show that N uptake and grain yield of maize are highest when gliricidia prunings are applied in October before planting. Evidently, for obtaining high maize yield and N uptake, sufficient amounts of mineral N have to be in the top soil early in the growing season. The substitution value of gliricidia prunings decreased with time of application in the order October > December > February. Mineral N availability in the topsoil was prolonged but N uptake by the crop was lower when the prunings were split applied than when applied at once in October.

Combination of inorganic N and gliricidia prunings increased N uptake and maize grain yield over the gliricidia prunings but the effect of inorganic fertilizer was only additive. The effect of addition of gliricidia prunings was exclusively a fertilizer N effect and no additional effects of organic materials were found.

Our first hypothesis that split application of gliricidia prunings can prolong mineral N in the topsoil was confirmed but our second hypothesis that this would increase nutrient use efficiency was rejected. Hence, a single application of prunings some weeks before planting is recommended, under the conditions of the current field experiment, with low and evenly distributed rainfall. This is discussed further also in chapter 8.

In practice, there will be not only high quality prunings from leguminous trees, but also low quality crop residues. Combining high and low quality materials is the subject of the next chapter (Chapter 5).

Appendix 4.1. Effect of gliricidia prunings and inorganic N (CAN) on mineral N content in the soil (0-20 cm); soil samples were collected on the indicated dates.

CAN-N (kg ha^{-1})		0	24	48	*Mean*
Date	Treatment				
23-10-01	Control	5.3	4.4	4.0	*4.6*
	DF	6.8	5.0	4.0	*5.3*
	OF	4.2	6.6	6.2	*5.7*
	OD	6.5	3.7	5.7	*5.3*
	ODF	6.0	4.0	4.1	*4.7*
	O	4.4	3.6	6.3	*4.8*
	OD2F	4.1	4.1	5.1	*4.4*
	CAN-72	7.1	5.0	5.4	*5.8*
	Mean	*5.6*	*4.5*	*5.1*	***5.1***
22-12-01	Control	15.3	15.7	18.1	*16.4*
	DF	14.2	15.7	20.3	*16.7*
	OF	26.9	32.0	36.2	*31.7*
	OD	30.1	31.3	34.5	*32.0*
	ODF	27.4	28.1	30.6	*29.3*
	O	40.8	42.3	44.9	*42.7*
	OD2F	27.5	28.4	29.6	*29.0*
	CAN-72	20.0	21.6	23.6	*21.7*
	Mean	*25.3*	*26.9*	*29.7*	***27.3***
22-01-02	Control	8.6	8.3	10.3	*9.1*
	DF	24.8	27.8	30.0	*27.5*
	OF	17.2	27.9	29.4	*24.8*
	OD	30.2	34.9	46.6	*37.2*
	ODF	23.8	26.1	29.7	*26.5*
	O	18.5	29.5	37.2	*28.4*
	OD2F	25.8	28.6	35.8	*30.1*
	CAN-72	12.0	14.5	20.6	*15.7*
	Mean	*20.1*	*24.7*	*30.0*	***24.9***
22-02-02	Control	7.1	7.3	8.2	*7.5*
	DF	17.9	20.9	27.0	*21.9*
	OF	15.6	16.4	19.0	*17.0*
	OD	24.0	26.4	33.4	*28.0*
	ODF	18.9	20.3	24.0	*21.1*
	O	11.9	12.4	18.5	*14.3*
	OD2F	22.9	24.3	29.5	*25.6*
	CAN-72	9.2	11.9	14.4	*11.8*
	Mean	*16.0*	*17.4*	*21.8*	***18.4***
22-03-02	Control	6.7	7.6	8.6	*7.6*
	DF	20.8	22.1	23.9	*22.3*
	OF	22.5	22.7	20.8	*22.0*
	OD	13.7	14.4	17.4	*15.2*
	ODF	19.9	23.6	24.8	*22.8*
	O	10.7	10.1	14.9	*11.9*
	OD2F	24.0	27.0	26.9	*26.0*
	CAN-72	8.6	9.1	10.7	*7.5*
	Mean	*15.9*	*17.1*	*18.5*	***17.2***

Gliricidia trees re-growth and litter fall on the ground after one year of not pruning

Two years old *sesbania sesban*