# NUTRIENT USE IN *LEUCAENA LEUCOCEPHALA* AND *CAJANUS CAJAN* IN MAIZE/CASSAVA ALLEY CROPPING ON *TERRE DE BARRE*, BENIN REPUBLIC

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**Key words**: alley cropping, cassava, cropping systems, *Leucaena*, maize, nutrient cycling

***Abstract:*** *On a Ferralic-haplic Acrisol (terre de barre non dégradée) in Southern Benin Republic, four years after the establishment of the hedgerows, yields of maize and cassava alley cropped with Leucaena leucocephala and Cajanus cajan were no better than those in control plots without hedgerows. Reduced crop yields were mainly due to competition with the hedgerows for water and nutrients, as indicated by lower soil moisture and nitrogen-nitrogen concentrations in the soil solution and high root-length densities in plots with hedgerows. Nitrogen balance data showed that the benefit to the food crop from the N applied in prunings was limited in this trial. In the long-term the hedgerows may improve soil productivity by enhancing the build-up of organic C and N and reducing leaching of nutrients, thereby increasing the efficiency of utilization of soil and fertilizer nutrients.*

## 1. Introduction

The kaolinitic soils of the humid and subhumid tropics are characterized by low moisture and cation retention and by soil acidification from continuous cropping due to the low buffering capacity of the soil. Soil fertility regeneration in traditional cropping systems is safeguarded by the fallow period. Fallow vegetation brings about nutrient recycling from the subsoil, $N_2$ fixation, nutrient accumulation in plant biomass and nutrient deposition in fallow litter. Burning the vegetation before cropping releases nutrients to the topsoil and corrects soil acidity [van Noordwijk and Diemont 1991]. Shortened fallow periods lead to declines in soil fertility. Alley cropping attempts to use the beneficial effects of trees to improve traditional cropping systems in a systematic way [Kang et al. 1989]. Some of the ways in which alley cropping is expected to sustain soil productivity were discussed by Young (1989). Although alley cropping has been reported to increase crop productivity [Kang et al. 1990], a quantitative understanding of the potentials and limitations of alley cropping on water and nutrient budgets is still missing. The purpose of the present study was to investigate the water and nutrient budget of maize/cassava intercropped with *Leucaena* and *Cajanus* hedgerows and those grown on plots with no hedgerows.

## 2. Materials and Methods

The experiment was established in 1986 at the Experimental Station of the International Institute of Tropical Agriculture (IITA) in the Republic of Benin, 15 km northwest of Cotonou. A bimodal rainfall distribution allows two maize crops a year. Long-term mean rainfall for first (main) and second (minor) rainy seasons are 758 mm and 266 mm. The soil is classified as a Ferralic-haplic Acrisol (FAO), locally known as *terre de barre non dégradée*. The soil (0-30 cm) contained: 87% sand; 3% silt; 10% clay; 0.81% organic C; 0.077% total N; 6.9 mg $kg^{-1}$truog P; $NH_4$-acetate exchangeable Ca, Mg, K, 2.58; 1.32; and 0.47 meq 100 $g^{-1}$ soil; and pH-$H_2O$ was 6.4. The experiment was designed as a modified split plot with four replications. Plots were not tilled. The main plots were: (i) control (no hedgerows), (ii) alley cropping with *Leucaena leucocephala* (Lam) de Wit, and (iii) *Cajanus cajan* (L.) Mill hedgerows, and (iv) two fertilizer rates (0 and 90-39-75 N-P-K in kg $ha^{-1}$). Two intercropping systems made up the subplots (1) a rotation of maize and cassava and (2) intercropped maize and cassava. Maize cv. TZSRW was planted in the first season and early maturing cv. TZESRW in the second season. The cassava cultivar was TMS 30572. Hedgerows were 4 m apart (5,000 plants $ha^{-1}$) with 4 rows of food crops between the hedgerows. Plant population per ha was 31,250 for maize, 15,625 for cassava and 46,875 for mixed cropping in the control treatments, and 25,000 maize 12,500 for cassava and 37,500 for mixed cropping in the alley cropped treatments. The hedgerows were not pruned in the establishment year (*Leucaena* 1986; *Cajanus* 1986 and 1989). Thereafter *Leucaena* was pruned to 0.35 m, 3 times in 1987 and 1988, and 5 times in 1989; *Cajanus* was pruned twice in 1987 and 3 times in 1988 to 0.75 m height. Fertilizer was applied in a single dose at the beginning of the first cropping period. For logistic reasons the nutrient budget was studied in only one replicate of the experiment.

Parameters measured:

1. Dry matter yield and nutrient content of harvested products (maize cobs, *Cajanus* and *Leucaena* pods, and wood, cassava tubers and shoots, crop residues returned to the soil after harvest, and prunings and leaf litter from the hedgerows).
2. Nutrient concentrations in the soil solution collected from depths of 30, 60, 90, 120, 150 cm at 14 day intervals using porous ceramic cups and applying an initial suction of approximately 600 hPa for 14 days.
3. Soil water tension at the above-mentioned profile depths at 7 day intervals was taken using a tensiometer and a portable puncture pressure transducer. Measurement at 200 cm soil depth was included from 1988.
4. Soil moisture up to 200 cm soil depth was measured with a neutron probe from 1989.
5. Root length densities in the soil up to 200 cm profile depth were measured using the core method in 1989. Roots were washed free from soil and separated into crop and hedgerow species; root length was then measured using the intersection method.

Conversion of yields, biomass production and nutrient uptake by the hedgerows and crops to a per-hectare basis was calculated by including the area occupied by the respective companion component crops and hedgerows [Rao and Coe 1992]. Since the hedgerows replaced one crop row per hectare of the alley cropped treatments, the crops and hedgerows occupied 0.8 ha and 0.2 ha respectively. These area weighting factors were used to adjust the per hectare seepage and leaching data for each system component in order to calculate total system figures.

Seepage and leaching were defined as water and associated convective nutrient flux (water flux times nutrient concentration) below 150 cm soil depth. The Darcy flux was calculated using measurements of hydraulic gradients (tensiometry) and an estimated unsaturated hydraulic conductivity versus water content function based on *in situ* measurements of the tension-moisture relationships and the saturated hydraulic conductivity. Laboratory measurements of the latter were adjusted by using simulation runs of a soil water balance model [Forest 1984] in the no-hedgerow maize treatment. Maize crop coefficients used to drive the model were taken from model calibration results on *terre de barre* in Southern Togo [Freteaud et al. 1987], and other parameters from *in situ* climatic and soil data.

## 3. Results

The hedgerows were established in 1986. *Cajanus* was much more vigorous than *Leucaena* in the establishment year, but in 1989 *Cajanus* had to be resown because of plant losses in 1987/88. The overall biomass production of *Leucaena* was therefore higher (table 1). Fertilizer application improved the growth of *Leucaena* hedgerows in the maize-cassava rotation. Mixed cropping reduced the leafy biomass yields of the hedgerows.

**Table 1. Total aboveground biomass production of *Leucaena* and *Cajanus* hedgerows and the biomass of prunings applied to the soil** (Mean of 4 years after sowing)

| | *Leucaena* | | *Cajanus* | |
|---|---|---|---|---|
| | Production | Application | Production | Application |
| | ............. ($t\ ha^{-1}yr^{-1}$) ............ | | | |
| Rotation (-NPK) | 8.91 | 7.23 | 7.64 | 6.59 |
| Rotation (+ NPK) | 10.16 | 7.14 | 6.60 | 5.54 |
| Mixed croppping (-NPK) | 5.95 | 4.86 | 4.91 | 4.22 |
| Mixed cropping (+NPK) | 5.57 | 4.20 | 3.99 | 3.34 |

A large amount of nutrients were recycled to the soil by the prunings and litter from the hedgerows especially those of *Leucaena* (table 2). Application of NPK only increased K recycling, indicating that the K supplying power of the soil was low.

The first season maize (figure 1), second season maize (table 3) and cassava (table 4) yields increased with NPK application. First season maize yields (figure 1) were variable between years and cropping systems. Mixed cropping reduced maize yields, especially in the drier years (1987 and 1989). Maize yields decreased under alley cropping by about 20% (mean of 4 years) which is equivalent to the surface area occupied by the hedgerows. Yield losses were generally higher in drier years. Alley cropping failed to increase first season maize yields during the 4 years of the experiment. Depression of second season maize (table 3) and cassava yields (table 4) were even more severe and only partially overcome by fertilizer application. The negative effects of alley cropping on crop yields might be due to delays in pruning the hedgerows in this trial and/or competition between hedgerow and crops for nutrients and water.

**Table 2. Nutrients recycled with prunings and litter fall of *Leucaena* and *Cajanus* hedgerows as affected by cropping system and fertilizer application** (Mean of 4 years)

| Treatment | N | P | K | Ca | Mg |
|---|---|---|---|---|---|
| | (kg ha$^{-1}$ yr$^{-1}$) | | | | |
| Rotation (-NPK) | | | | | |
| *Leucaena* | 189.2 | 9.7 | 30.4 | 93.6 | 34.8 |
| *Cajanus* | 128.6 | 7.5 | 19.6 | 57.1 | 25.4 |
| Rotation (+NPK) | | | | | |
| *Leucaena* | 200.6 | 11.9 | 69.2 | 89.8 | 32.0 |
| *Cajanus* | 112.5 | 7.6 | 26.2 | 42.7 | 18.9 |
| Mixed cropping (-NPK) | | | | | |
| *Leucaena* | 133.4 | 7.0 | 25.9 | 71.1 | 25.6 |
| *Cajanus* | 84.1 | 4.7 | 14.0 | 32.4 | 16.0 |
| Mixed cropping (+NPK). | | | | | |
| *Leucaena* | 125.2 | 7.6 | 49.5 | 44.6 | 18.9 |
| *Cajanus* | 74.3 | 4.8 | 15.4 | 29.5 | 11.2 |

Nutrient concentrations ($NO_3^-$, $SO_4^{2-}$, $Ca^{2+}$, $Mg^{2+}$, $K^+$) of the soil solution in the main rooting zone of monocropped maize and cassava were generally higher than when intercropped with *Leucaena* and *Cajanus*, as shown for $NO_3^-$ (figure 2). In particular, at the beginning of the cropping period, $NO_3^-$ concentrations at 30 cm profile depth were much higher in the cropped plots without hedgerows than with *Leucaena* hedgerow (F) treatments. Lowest $NO_3^-$ concentrations were always measured under the hedgerows (H). During the cropping periods $NO_3^-$ concentrations remained low even when prunings high in N, were applied in the alley cropped system. It was only in 1989, when *Leucaena* was pruned more intensively, that higher nitrate concentrations were recorded in alley cropping plots with *Leucaena*. The $NO_3^-$ concentrations at 150 cm depth show an inverse picture with a time lag indicating that with alley cropping less $NO_3^-$ moved down to the subsoil. Competition for water between food crops and hedgerows was especially clear during the dry year in 1987 (figure 3). Periods of low rainfall led to an increase of soil water tensions (depletion of soil moisture) which was higher in plots with hedgerows. High intensity rainfall in the middle and at the end of the first season

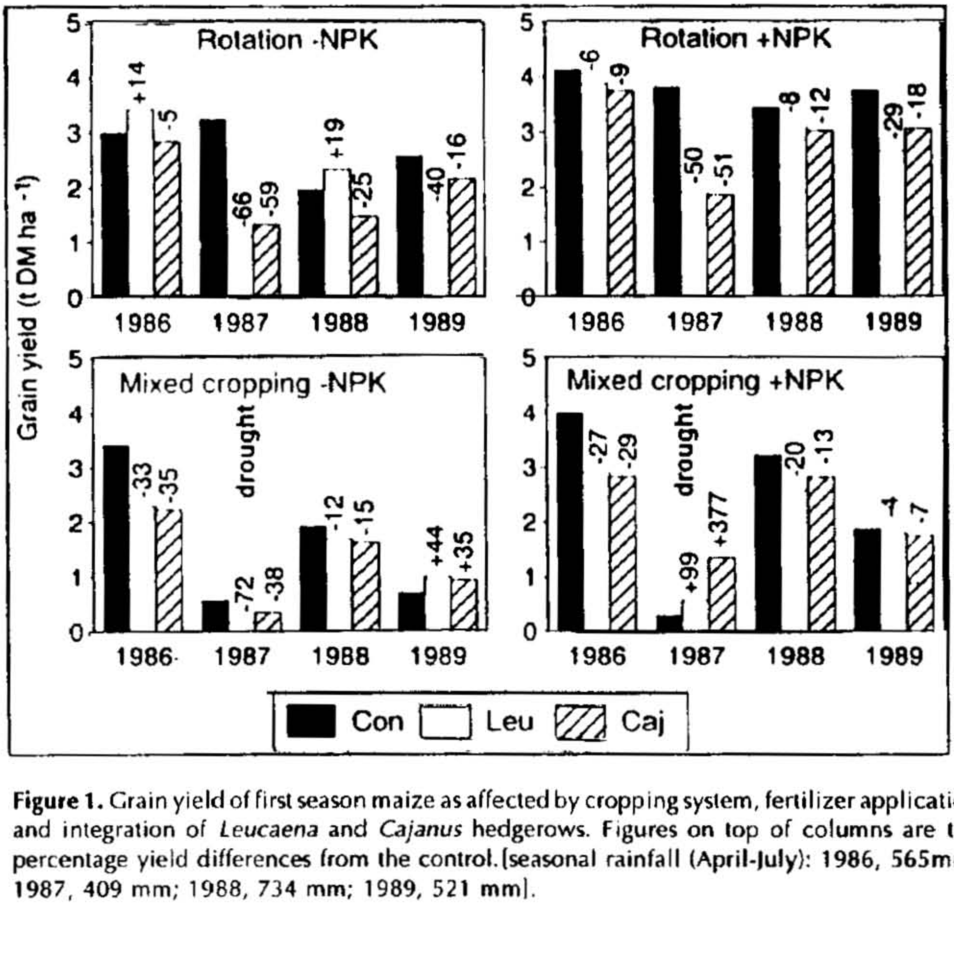


**Figure 1.** Grain yield of first season maize as affected by cropping system, fertilizer application and integration of *Leucaena* and *Cajanus* hedgerows. Figures on top of columns are the percentage yield differences from the control. [seasonal rainfall (April-July): 1986, 565mm; 1987, 409 mm; 1988, 734 mm; 1989, 521 mm].

rewetted the soil to 150 cm within a relatively short period of time. Dry soil under second season maize shows that maize could not utilize soil water deeper than 150 cm, but *Leucaena* and *Cajanus* could. There was competition in the top 150 cm due proliferation of the roots of the hedgerow under the crops (figure 4).

**Table 3. Second season maize grain yields (kg ha$^{-1}$) as affected by fertilizer applied to the first season maize and integration of *Leucaena* and *Cajanus* hedgerows** (Mean of 4 years of rotation)

| | Absolute | | | Relative % | |
|---|---|---|---|---|---|
| | -NPK | +NPK | Mean | -NPK | +NPK |
| Control | 885 | 1096 | 991 | 100 | 100 |
| *Leucaena* | 327 | 630 | 479 | 37 | 57 |
| *Cajanus* | 157 | 306 | 232 | 18 | 28 |
| Mean | 456 | 677 | 567 | | |

**Table 4. Root yield (kg DM ha$^{-1}$) of cassava as affected by cropping system, fertilizer application and alley cropping with *Leucaena* and *Cajanus* hedgerows** (mean of 2 crops in 4 years)

| | Absolute | | | Relative % | |
|---|---|---|---|---|---|
| | -NPK | +NPK | Mean | -NPK | +NPK |
| **Control** | 8146 | 7357 | 7752 | 100 | 100 |
| *Leucaena* | 4259 | 5265 | 4762 | 52 | 72 |
| *Cajanus* | 4264 | 6214 | 5239 | 52 | 84 |
| Mean | 5556 | 6279 | 5918 | | |
| **Mixed cropping control** | 2909 | 3931 | 3420 | 100 | 100 |
| *Leucaena* | 1889 | 3682 | 2786 | 65 | 94 |
| *Cajanus* | 2377 | 5131 | 3754 | 82 | 131 |
| Mean | 2392 | 4248 | 3320 | | |
| Total Mean | 3974 | 5264 | 4619 | | |

Nutrient losses from the rooting zone through leaching depend on nutrient concentrations in the soil solution and the amount of seepage. Because of seepage below a depth of 150 cm, a high percentage of the rainfall was unavailable to crops (figure 5). The negative correlation between the annual precipitation and the amount of seepage for the corresponding year showed clearly that the amount of seepage was affected more by rainfall distribution than the total amount of rainfall. Fertilizer application under mixed cropping reduced seepage below 150 cm because of higher transpiration of fertilized crops, which is associated with better growth and higher plant population; prolonged soil cover also reduced normal water lost through seepage. The effect of the hedgerows on seepage was not consistent, because it depended on rainfall distribution at the time of pruning; high rainfall at pruning led to increased seepage (data not shown).

The amount of nutrients leached (represented by $NO_3^-$ leaching in figure 6) depended more on the nutrient concentration in the soil solution than on seepage.

There was no consistent difference in $NO_3^-$ leaching among the different fertilizer treatments and crops. Very little $NO_3^-$ leaching, however, could be measured under mixed cropping. In contrast to seepage, presence of *Leucaena* hedgerows decreased $NO_3^-$ leaching in most of the years. The effect of *Cajanus* was less consistent; this was due to poor stands in 1988 and re-establishment in 1989.

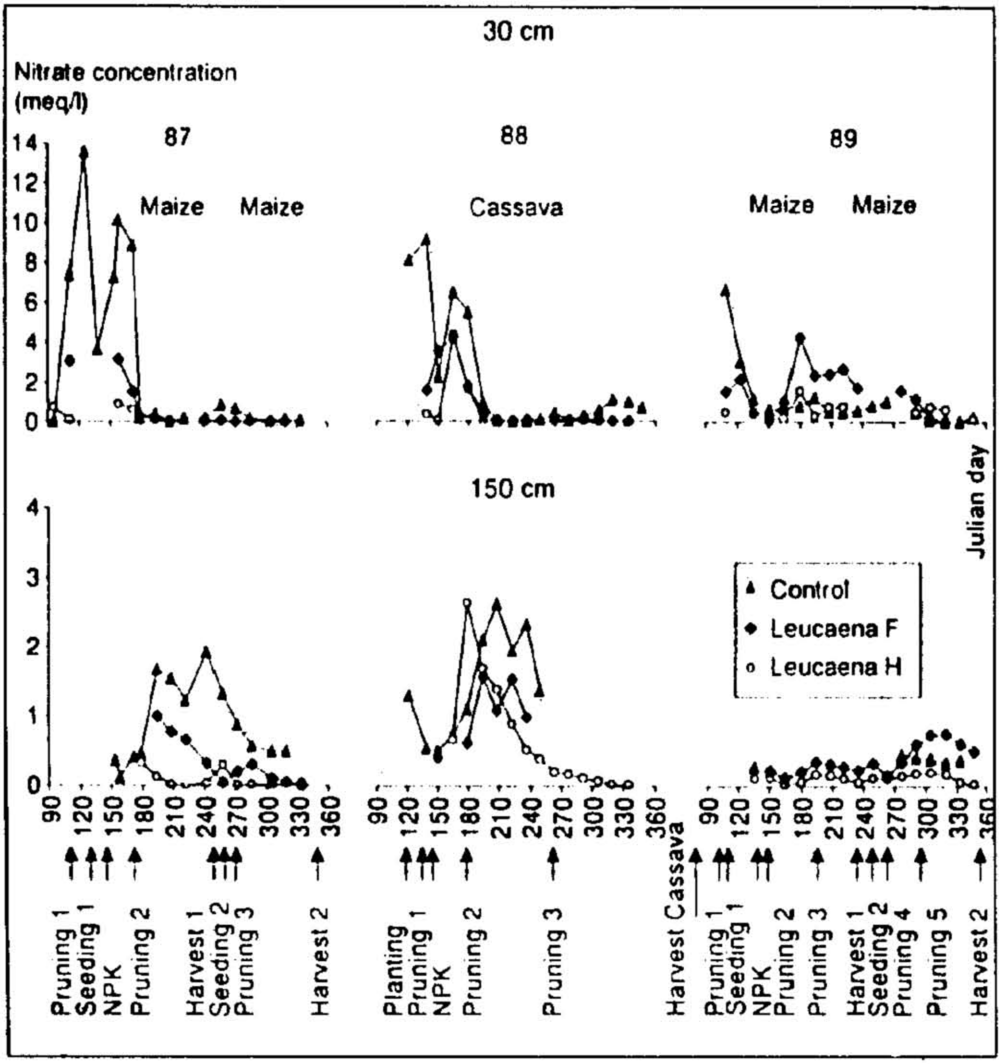


**Figure 2.** Nitrate concentrations in soil solutions at two profile depths under fertilized maize-cassava rotation without and with *Leucaena* hedgerows. Soil solution in the *Leucaena* treatment was sampled in the hedgerow (H) and in the alleys under food crop (F).

**Table 5. Budget of nitrogen export and import to the soil (kg N $ha^{-1}$ $yr^{-1}$) as affected by fertilizer application and alley cropping with *Leucaena* and *Cajanus* hedgerows** (Means of 3 years, 1987-1989)

| Treatment | Export | | | | Import | | | Diff.1 | Recycling | | | Diff.2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | FC[a] | Hedge[b] | Leach[c] | ΣE | Rain | Fert. | ΣI | ΣI - ΣE | FC | Hedge | ΣR | (ΣI + ΣR)-ΣE |
| **Rotation -NPK** | | | | | | | | | | | | |
| Control | 84.1 | 0 | 32.3 | 116.4 | 4.0 | 0 | 4.0 | -112.4 | 47.8 | 0 | 47.8 | -64.6 |
| *Leucaena* | 53.5 | 34.3 | 5.9 | 93.7 | 4.0 | 0 | 4.0 | -89.7 | 33.7 | 232.8 | 266.5 | 176.8 |
| *Cajanus* | 58.2 | 17.0 | 13.6 | 88.8 | 4.0 | 0 | 4.0 | -84.8 | 28.6 | 136.9 | 165.5 | 80.7 |
| **Rotation + NPK** | | | | | | | | | | | | |
| Control | 140.6 | 0 | 18.4 | 159.0 | 4.0 | 90.0 | 94.0 | -65.0 | 73.6 | 0 | 73.6 | 8.6 |
| *Leucaena* | 94.6 | 41.4 | 4.5 | 140.5 | 4.0 | 90.0 | 94.0 | -46.5 | 57.8 | 236.6 | 294.4 | 247.9 |
| *Cajanus* | 107.9 | 9.5 | 19.9 | 137.3 | 4.0 | 90.0 | 94.0 | -43.3 | 60.4 | 113.1 | 173.5 | 130.2 |
| **Mixed crop'g -NPK** | | | | | | | | | | | | |
| Control | 93.7 | 0 | 3.2 | 96.9 | 4.0 | 0 | 4.0 | -92.9 | 51.5 | 0 | 51.5 | -41.4 |
| *Leucaena* | 43.6 | 31.8 | 1.3 | 76.7 | 4.0 | 0 | 4.0 | -72.7 | 32.8 | 168.4 | 201.2 | 128.5 |
| *Cajanus* | 66.7 | 8.9 | 5.6 | 81.2 | 4.0 | 0 | 4.0 | -77.2 | 29.2 | 96.1 | 125.3 | 48.1 |
| **Mixed crop'g +NPK** | | | | | | | | | | | | |
| Control | 135.8 | 0 | 5.5 | 141.3 | 4.0 | 90.0 | 94.0 | -47.3 | 89.4 | 0 | 89.4 | 42.1 |
| *Leucaena* | 99.0 | 31.1 | 2.4 | 132.5 | 4.0 | 90.0 | 94.0 | -38.5 | 59.6 | 152.5 | 212.1 | 173.6 |
| *Cajanus* | 150.1 | 8.9 | 12.3 | 171.3 | 4.0 | 90.0 | 94.0 | -77.3 | 65.4 | 66.0 | 131.4 | 54.1 |

[a]FC = Food crops; [b]Hedgerow; [c]Amount leached

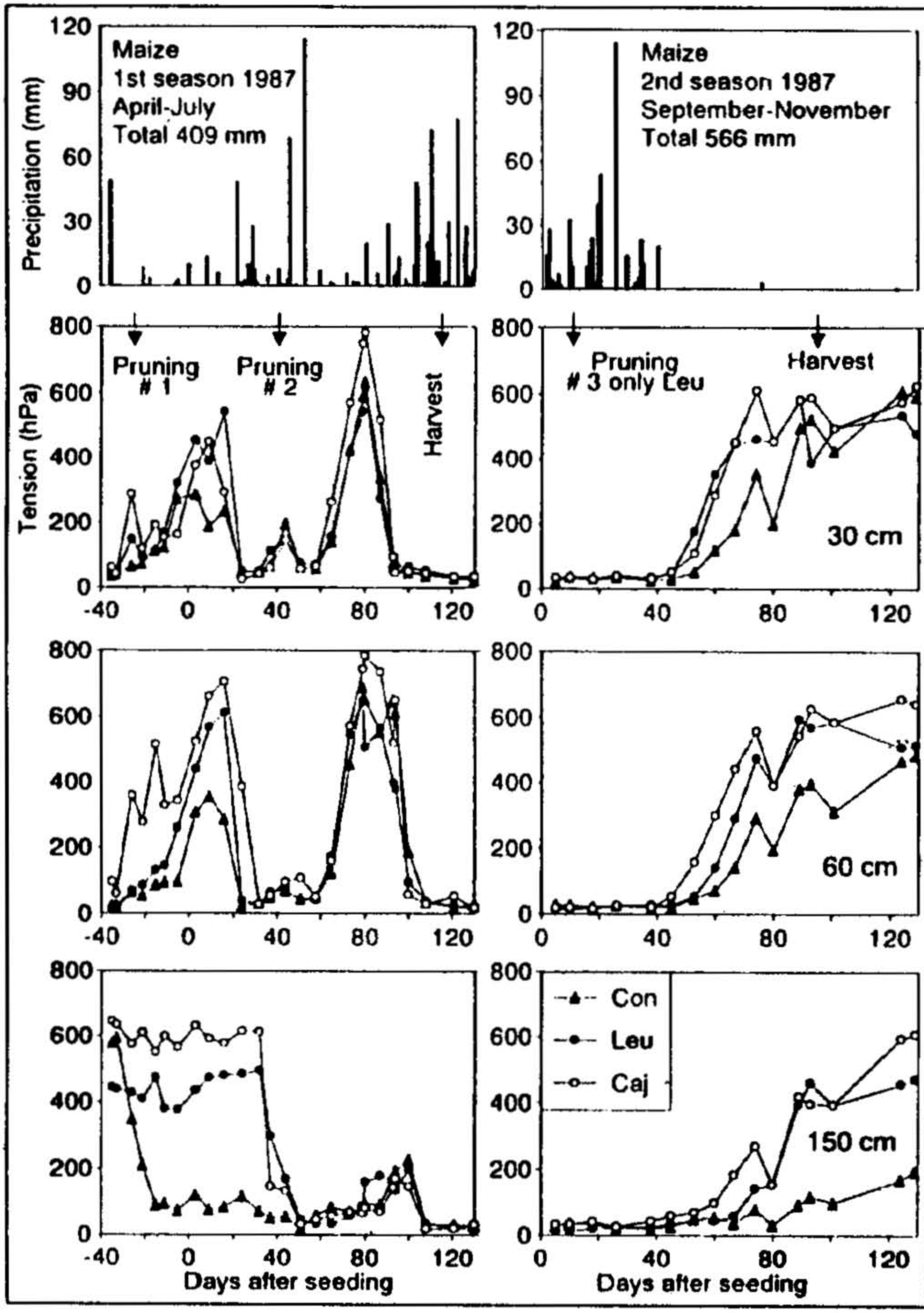


**Figure 3.** Precipitation and soil-water tensions under fertilized maize in 1987 as affected by alley cropping with *Leucaena* and *Cajanus* hedgerows

Quantification of nutrient export, import and recycling enabled a nutrient budget to be drawn up from this soil. In table 5 the N-budget is shown comparing only export and import (Diff. 1). Depletion of soil-N is apparent. Application of 90kg N $ha^{-1}$ $yr^{-1}$ was not sufficient to compensate for the N export. Interplanting *Leucaena* and *Cajanus* hedgerows lessened the deficit, by reducing leaching losses. When N recycled by crop residues, prunings and litter fall is included as import (Diff. 2) the N budgets of the controls are approximately balanced provided N is applied. Owing to the high N content of the prunings, the N budgets of the alley-cropping systems indicate N gains from $N_2$ fixation.

Over 4 years, such a high annual input of N should increase in soil N content considerably. As shown in table 6, there was only a tendency towards higher N and C contents of the surface soil after 4 years of alley cropping compared to the control. A significant reduction in soil pH in fertilized plots was not prevented by alley cropping.

## 4. Discussion

Under the conditions of this experiment, no positive effect on food crop yield of interplanting *Leucaena* and *Cajanus* hedgerows could be demonstrated during 4 years. When fertilizer was used, lower yields of maize and cassava could be explained by the 'loss' of the cropped field area to the hedgerows. However, in unfertilized treatments yield losses were generally much higher (figure 1, tables 3, 4). This can be explained by competition between the hedgerow and the food crops for water (figure 3) and nutrients, especially nitrate (figure 2). In contrast to the results of Kang et al. (1985), showing that on an Alfisol in southern Nigeria maize took up water mainly from the upper horizons, while *Leucaena* obtained water from the deeper soil horizons, the data presented here, show that in this trial *Leucaena* and *Cajanus* roots readily exploit the same soil as the crops (figure 4).

The biomass and nutrient (especially N) contribution to the soil from *Leucaena* prunings was substantial (tables 1, 2)) as reported from other places [Kang et al. 1990]. *Leucaena* performed better than *Cajanus* at this site because it was less sensitive to pruning and more competitive with the food crops whereas *Cajanus* needed to be resown at least every second year. Apparently little N was transferred from the hedgerows to the food crops. Since *Cajanus* and *Leucaena* prunings decompose rapidly [Wilson et al. 1986], very little accumulation of organic C and nutrients was found in the 4 years of this study (table 6). This indicates that a high proportion of the N released from the prunings is being utilized by the hedgerows. Mulongoy and Sanginga (1990) also reported low N transfer to maize and assumed that most of the N in the prunings was either recovered by the trees or lost through leaching and volatilization.

The main positive effect of interplanting *Leucaena* hedgerows in the maize-cassava rotation system was a decrease in the amounts of nutrients, especially $NO_3^-$, leached down below 150 cm (figure 6). The real losses would have been even less because *Leucaena* roots penetrate much deeper into the soil. Less $NO_3^-$ was leached under maize/cassava mixed cropping than under rotation. Therefore, the advantage of alley cropping was lower under mixed cropping. Several factors may have contributed to the failure of hedgerows to increase crop yields on these degraded soils.

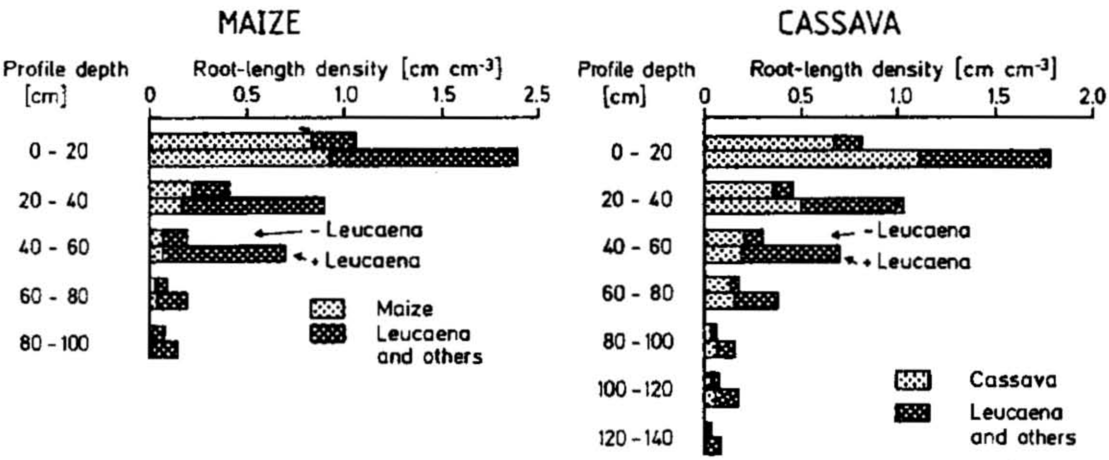


**Figure 4.** Root length densities under maize [37 day after planting (DAP)] and cassava (65 DAP) without (-) an with (+) *Leucaena* hedgerows in 1989

**Table 6. Carbon and N content and pH of the surface soil before the experiment and after 4 years of maize/cassava rotation as affected by fertilizer application and integration of *Leucaena* and *Cajanus* hedgerows**

| | % C | | % N | | pH-$H_2O$ | |
|---|---|---|---|---|---|---|
| | - NPK | + NPK | - NPK | + NPK | - NPK | + NPK |
| 1986 Fallow | 0.81 | | 0.077 | | 6.40 | |
| 1990 Control | 0.71 | 0.67 | 0.060 | 0.056 | 6.13 | 5.75 |
| *Leucaena* | 0.76 | 0.84 | 0.064 | 0.070 | 6.13 | 5.68 |
| *Cajanus* | 0.77 | 0.81 | 0.064 | 0.067 | 6.13 | 5.63 |

### 5.1 Fertility of the soil

In the first year there was a clear response to NPK application, mainly due to N and K, even though the soil was fertile, as shown by mean yields of 2.7 $t/ha^{-1}$ of first season maize and 8 t $ha^{-1}$ root DM yield of cassava in the unfertilized 4 year rotation

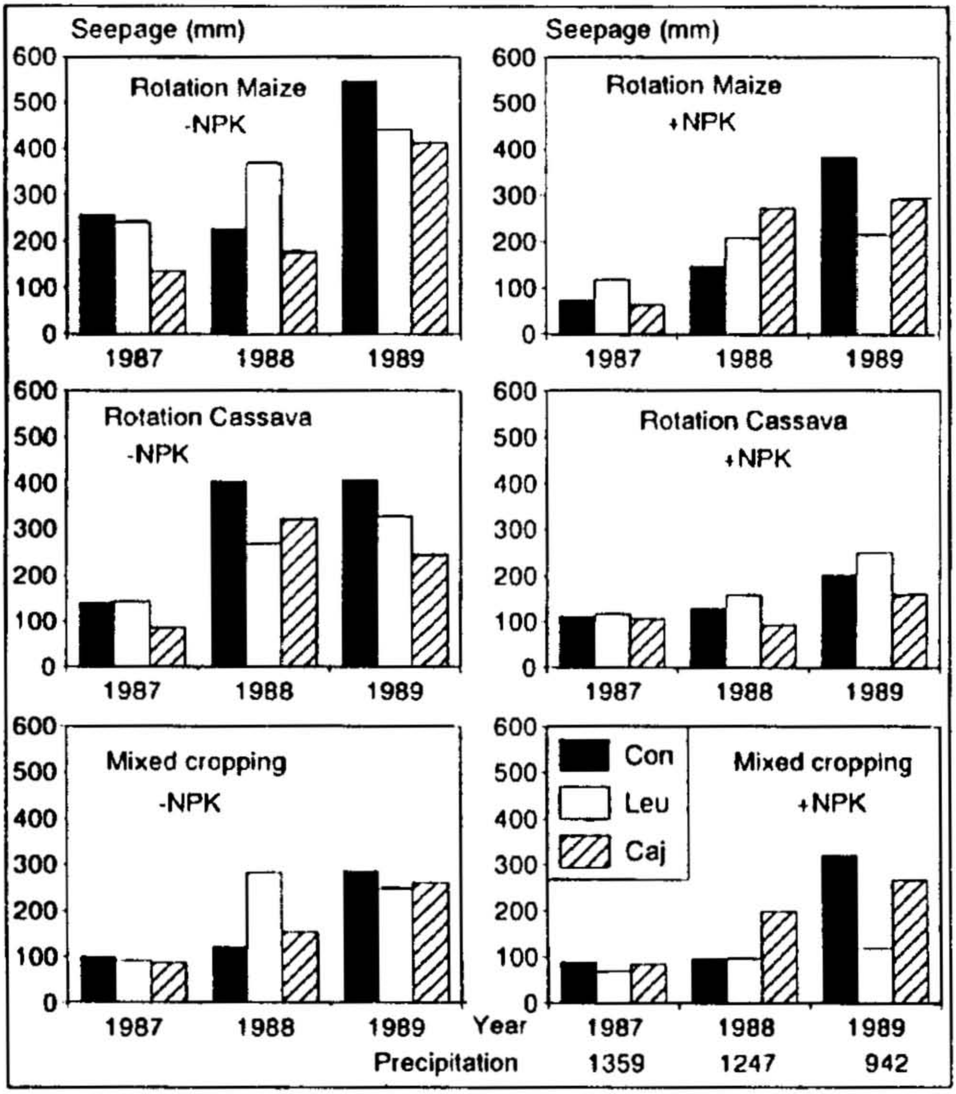


**Figure 5.** Seepage below 150 cm profile depth as affected by cropping system, fertilizer application, and integration of *Leucaena* and *Cajanus* hedgerows

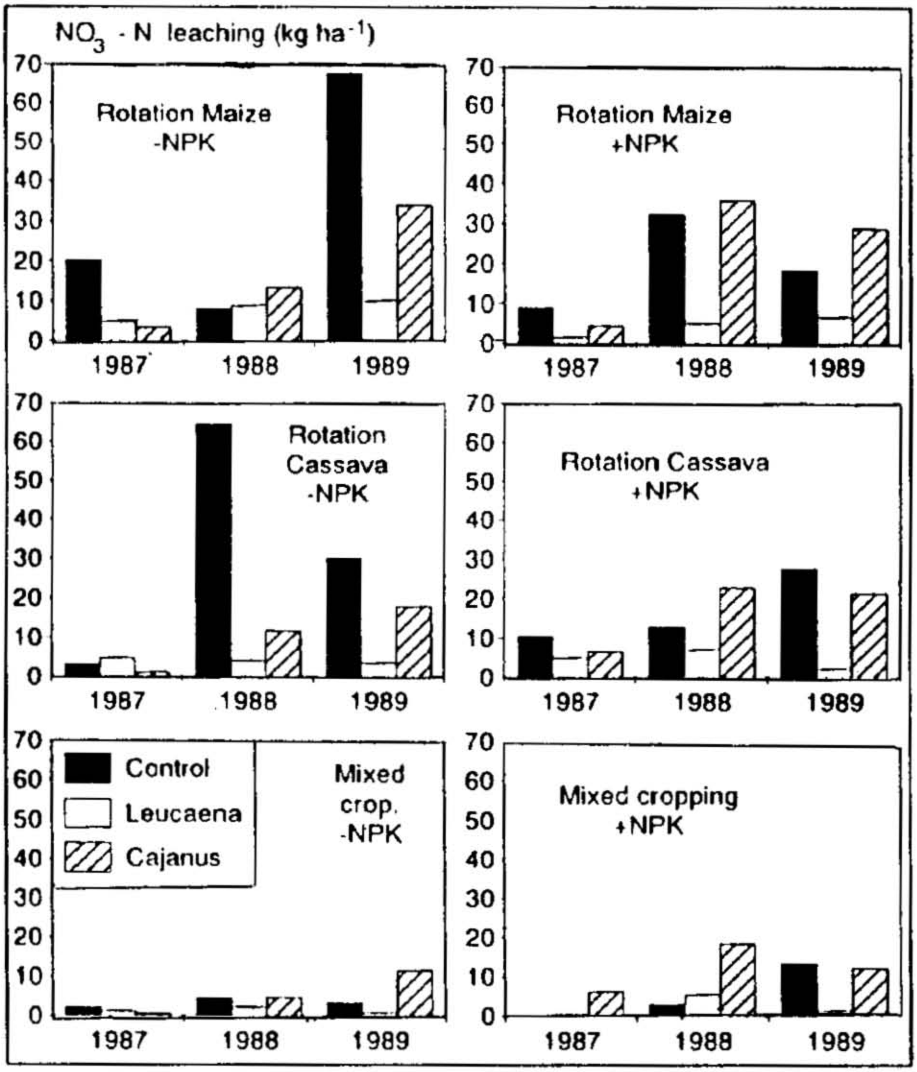


**Figure 6.** Nitrate-N leaching below 150 cm profile depth as affected by cropping system, fertilizer application, and integration of *Leucaena* and *Cajanus* hedgerows

system. The *high* soil productivity was due to the good physical structure of the surface soil which allowed deep rooting and high nutrient use efficiency: apparent fertilizer use-efficiency in the plots without hedgerows was 78 (100), 30 (41), and 72 (87) per cent for N, P, K, in rotation (mixed cropping) respectively. Furthermore, run-off and erosion were negligible because of the high infiltration rate of the soil and lack of slope.

### 5.2 Cropping system and management of the controls (without hedgerow)

Cassava, one of the main components of this study, is a perennial. Therefore, in the rotation system, every second year the soil was protected by a vegetation cover over most of the year. With its deep root system (figure 4), cassava is capable of recovering water and nutrients deep in the soil and thereby reducing the loss of mobile nutrients. Large amounts of organic matter (and nutrients) were recycled to the soil surface as cassava leaf litter (up to 4 t DM $ha^{-1}$) and maize crop residues (up to 5 t DM $ha^{-1}yr^{-1}$). These undoubtedly contributed to the maintenance of favorable The beneficial effects of crop residues on the productivity of tropical soils have recently been demonstrated by Vlek (1990) and Kretzschmar et al. (1991). Applications of 90 kg N, 39 kg P and 75 kg K $ha^{-1}yr^{-1}$ were sufficient to render positive the balance of these nutrients for the surface soil (only shown for N in table 5). The Ca and Mg balances of maize/cassava rotations, were, however, negative in the absence of hedgerows (data not shown).

### 5.3 Management of the hedgerows

In the experimental plots, the hedgerows apparently competed strongly with crops. Lawson and Kang (1990) reported that if pruning is done frequently during critical crop growth periods, competition for light, water and nutrients can be reduced. However, *Cajanus* is not resistant to pruning, and increasing the frequency of pruning of *Leucaena* from 3 (1987, 1988) to 5 (1989), which reduced total biomass production and N contribution substantially (data not shown), did not increase food-crop yields (figure 1). Competition between the crops and the hedgerows might be reduced by improving the timing of pruning the hedgerows in relation to crop growth and/or by better plant arrangement within the alleys or restriction of pruning and fertilizer application to the area occupied by the crops. Preventing the roots of the hedgerows from growing into the rooting zone of the food crop would only be practical in mechanized agriculture.

The results clearly show how interplanting *Leucaena* and *Cajanus* hedgerows in cropping systems can potentially increase nutrient transfer to the surface soil and reduce nutrient leaching losses. However, this potential can result in improved crop yields during the first years of establishment of the system only if competition between the hedgerows and the crops for water and nutrients (and light) is reduced through improved hedgerow management.

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**References**

FAO (Food and agriculture organization) (1989) FAO/UNESCO soil map of the world. Revised legend. FAO, Rome, Italy.

Forest F (1984) Simulation du bilan hydrique des cultures pluviales. Présentation et utilisation du logiciel BIP. Rapport IRAT/CIRAD, Montpellier, France.

Freteaud JP, Poss R and Saragoni H (1987) Ajustement d'un modèle de bilan hydrique à des mesures tensio-neutroniques in situ sous culture de mais. Agronomie Tropical 42: 94-102.

Kang BT, Grimme H and Lawson TL (1985) Alley cropping sequentially cropped maize and cowpea with *Leucaena* on a sandy soil in Southern Nigeria. Plant and Soil 85: 267-277.

Kang BT, Van Der Kruijs ACBM and Couper DC (1989) Alley cropping for food crop production in the humid and subhumid tropics. In: Kang BT and Reynolds L, eds, Alley Farming in the Humid and Subhumid Tropics, pp 16-26. IDRC, Ottawa, Canada.

Kang BT, Reynolds L and Atta-Krah AN (1990) Alley Farming. Advan. in Agron. 43: 315-359.

Kretzschmar RM, Hafner H, Bationo A and Marschner H (1991) Long and short-term effects of crop residues on aluminium toxicity, phosphorus availability and growth of pearl millet in an acid sandy soil. Plant and Soil 136: 215-223.

Lawson TL and Kang BT (1990) Yield of maize and cowpea in an alley cropping system in relation to available light. Advances in Agronomy, Agriculture and Forest Meteorology Fertilizer Research 52: 347-357.

Mulongoy K and Sanginga N (1990) Nitrogen contribution by *Leucaena* in alley cropping. IITA Res. Rep. 1: 14-17.

Van Noordwijk M and Diemont WH (1991) Positive and negative aspects of shifting cultivation. In: Diemont WH and Smiet AC, eds, Proceedings Workshop Low-Input Agriculture in Acid Upland Soils. SECM, Bogor, Indonesia. Spec. Publ. No. 2: 2-9.

Vlek PLG (1990) The role of fertilizers in sustaining agriculture in sub-Saharan Africa. Fert Res 26: 327-339.

Rao MR and Coe R (1992) Evaluating the results of agroforestry research. Agroforestry Today, 4(1): 4-9.

Sanchez PA (1987) Soil productivity and sustainability in agroforestry systems. In Steppler HA and Nair PKR, eds, Agroforestry: A decade of development, pp. 205-223. ICRAF, Nairobi, Kenya.

Wilson GF, Kang BT and Mulongoy K (1986) Alley cropping: trees as sources of green manure and mulch in the tropics. Biological Agriculture and Horticulture 3: 251-267.

Young A (1989) Agroforestry for Soil Conservation. CAB International, ICRAF, Wallingford, U.K.