# HAITI PRODUCTIVE LAND USE SYSTEMS

**Haiti**

**SOUTH-EAST CONSORTIUM FOR INTERNATIONAL DEVELOPMENT**
**AND**
**AUBURN UNIVERSITY**

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## The Effects of Alley Cropping and Other Soil Conservation Practices on Maize (*Zea mays*) Yields over Two years of Cropping

**by**
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| | |
|---|---|
| AF II | Agroforestry II |
| CARE | CARE International, a project implementor |
| PADF | Pan American Development Foundation, a project implementor |
| PLUS | Productive Land Use Systems |
| SAS | Statistical Analysis Systems |
| SECID | South-East Consortium for International Development |
| USAID | United States Agency for International Development |

# EXECUTIVE SUMMARY


The effects of different soil conservation practices on crop and hedgerow biomass yields were assessed under lowland conditions in Haiti over a period of two years. The trial was conducted at Pernier (1300 mm annual rainfall) on a north-facing slope of 30 %. The soil is a fine, mixed isohyperthermic Lithic Eutropept with pH = 8. Soil conservation structures spaced 4 m apart on contours were compared to a control without structure. The treatments tested were: stone walls; contour canals; alley cropping with hedgerows of *Leucaena leucocephala*; alley cropping with rows of *Panicum maximum*; hedgerows of *L. leucocephala* and *P. maximum*; alley cropping with fertilizer; control without structure. Two years after *Leucaena* was established, maize was planted two seasons per year. Plots with vegetative structures had 20 % fewer maize plants than did other plots, but received prunings as mulch.

Large differences in maize yields were recorded among the treatments over the four seasons:

- During the first two cropping seasons, alley cropping gave lower yields than did other practices. From the third crop, alley cropping with fertilizer resulted in higher yields than conventional practices.
- In the fourth season, alley cropping with *Leucaena*, with or without fertilizer, gave higher maize yields than all other practices despite the loss of land area of the hedgerows. Stone walls, contour canals and grass rows gave the same yield as the control without structure.
- Maize yields steadily decline in absence of alley cropping while yields with alley cropping remain stable or increase over time.
- Use of moderate amount of fertilizer in combination with hedgerows increased maize yields from the second cropping season.
- Grass rows supply much less biomass to serve as mulch than does *Leucaena*.

## Comparisons Among Alley Cropping Treatments

- Hedgerow and fertilizer yielded consistently more maize grain than hedgerow with grass and hedgerow alone treatments in all four seasons.
- The combination of *Leucaena* hedgerow with grass resulted in higher maize grain and biomass yields than hedgerow alone over the four seasons
- In terms of biomass yields, *Leucaena* hedgerow with grass was the most productive followed by the hedgerow and fertilizer treatment in all seasons.

## Implications and Recommendations

- Under proper management, alley cropping, with or without fertilizer, maintains crop yields over time.
- Stone walls, contour canals and grass rows are effective in reducing soil erosion, but to sustain crop yields, should be combined with practices that enhance soil organic matter and fertility.
- This trial should be continued for more seasons to confirm trends observed in the third and fourth seasons.
- Economic analysis should be conducted on the effect of combining grass with *leucaena* hedgerows to determine if the apparent additional crop and biomass yields merit the additional costs of planting and maintaining the grass rows.
- Economic analysis should be conducted on the effect of fertilizer application in conjunction with soil conservation practices such as alley cropping.
- Additional research is justified on alley cropping and other conservation practices that return substantial amounts of nitrogen rich biomass to the soil.
- The effect of organic applications on phosphorus fixation in calcareous soil should be studied.

# CREOLE SUMMARY

Objektif etid sa-a se konpare efè kèk pratik konsèvasyon sòl genyen sou pwodiksyon kilti ak pwodiksyon ranp lesena nan kondisyon peyi Dayiti sou yon perioòd de (2) lane. Etid la te realize nan Pènye. Sit la se yon tè pandye nan direksyon nò (30 % pant) ki resevwa 1300 mm lapli chak ane. Sòl la se yon tè fen ki gen yon pH = 8. Plisyè teknik konsèvasyon (estrikti yo gen yon distans 4 m ki separe yo) te kompare ak yon temwen ki pa gen estrikti. Teknik sa yo se te: misèk; kanal kontou; ranp lesena (*Leucaena leucocephala*) tou sèl; ranp graminé (*Panicum maximum*); ranp lesena ak graminé; ranp lesena ak angrè; temwen san estrikti. Mayi a te plante de (2) fwa chak ane, de (2) lane apre ranp lesena yo te enstale. Nan pasèl ki gen ranp yo, mwens mayi te simen (20 % mwens) pase nan lot pasèl yo. Fèy ak branch vèt ki koupe nan ranp yo te simen nan mitan ranp yo.

Nou konstate gwo diferans nan randman mayi pou divès teknik yo:

- Nan de (2) premye sezon yo, teknik ranp vivan ak lesena te bay mwens randman mayi pase lòt pratik yo. A pati twazyèm sezon an, ramp lesena ak angrè te bay plis randman pase lòt teknik yo.
- Nan katryèm sezon an, randman mayi nan mitan ranp lesena yo, avèk oubyen san angrè, te depase randaman tout lòt teknik yo malgre te gen mwens pie mayi nan mitan ranp yo. Misèk, kanal kontou, ranp graminé yo te bay menm randman ak temwen an ki pa gen estrikti.
- Nan kote ki pa gen ranp lesena, randman mayi a te bese apre chak sezon. Nan mitan ranp lesena yo, randman mayi a te ogmante apre chak sezon.
- Lè nou itilize yon ti kantite angrè nan mitan ranp lesena yo, randman mayi a te ogmante plis apre chak sezon.
- Ranp graminé yo te bay mwens randman biomas pase ranp lesena yo.

**Konparezon ant Ranp Lesena**

- Nan tout kat (4) sezon yo randman mayi nan ranp lesena ki te gen angrè a te pi plis ke nan lòt ranp lesena yo (lesena ak graminé, lesena tou sèl).
- Ranp lesena ak graminé a podwi plis mayi ak plis biomas ke ranp lesena tou sèl la nan tout kat (4) sezon yo.
- Pou pwodiksyon biomas ranp yo, se pasèl lesena ak graminé a ki te podwi plis biomass. Pasèl lesena ak angrè a te vini apre li nan tout sezon yo.

**Rekòmandasyon**

- Itilizasyon ak bon jerans ranp lesena avèk oubyen san angrè pèmèt bon jan pwodiksyon pou plis tan.
- Misèk, kanal kontou, ranp gramine bon pou kenbe tè men teknik sa yo pa pèmèt pwodiksyon kilti kenbe lontan si yo pa asosye ak lòt teknik ki ka amelyore kantite matyè òganik ak fètilite tè-a.
- Travay sa-a dwe kontinye pou bon jan konfimasyon rezilta twazyèm ak katryèm sezon yo.
- Analiz ekonomik ta dwe fèt nan ka lesena asosye ak graminé a pou wè si kantite depans pou enstalasyon ak travay anplis graminé a jistifye pou ogmantasyon randman pasèl la bay.
- Analiz ekonomik ta dwe fèt tou sou efè angrè a pa rapò a teknik ranp lesena san itilizasyon angrè.
- Lòt etid nesesè sou ranp vivan ak lòt teknik konsèvasyon ki ka pòte pi bon amelyorasyon nan kalite tè a.
- Efè aplikasyon matyè òganik sou jan tè kalkè yo kapte fosfò nan sòl la ta merite etidye tou.

# INTRODUCTION

Soil degradation has long been recognized as one of the most critical constraints to crop production in hillside farming systems. This process is often associated with high rates of soil erosion, which results from cropping on steep slopes without the use of conservation measures, from overgrazing and from clear cutting of trees. It not only severely limits yields but also substantially reduces the response to fertilizers or other inputs.

In Haiti, increasing population density during the last three decades and lack of more suitable land have increased the pressure on sloping lands. Shifting cultivation, with long fallow periods to restore soil fertility, formerly characterized the hillside agriculture systems in Haiti. This system becomes soil degrading when fallow periods are drastically reduced by pressure of population upon lands. Continuous cropping without appropriate soil conservation practices, combined with the method of land preparation practiced by Haitian farmers, gives rise to increasing rates of erosion, soil degradation and a decline in agricultural sustainability. Farmers are faced with a gradual decrease in crop yields, and in many instances, this degradation process has led them to abandon lands which were previously productive. Unless appropriate farming systems are evolved and adopted by farmers on sloping lands, these fragile areas which are most predominant in Haiti will in the near future become unproductive for annual crops.

### Soil Conservation Practices in Haiti

In order to reduce soil loss and stabilize crop yields, various soil conservation measures are used in parts of Haiti. Incorporation of crop residues in strips are recommended by extension agents in Northwest Haiti to enhance nutrient cycling and provide a temporary filter barrier to runoff. Deep furrows are recommended in Southern Haiti to conserve soil and decrease runoff. Stone walls are constructed in some parts to conserve soil on slopes and grass rows have been suggested as a means to supplement the hedgerows as a erosion-control device. The grass can also serve as a livestock feed. Lal, 1984 (cited in Lal, 1989b) reported that erosion can also be controlled by no-till, cover crops or grass strips. In a trial in Sri Lanka, contour legume strips of 0.75 m, supplemented by field residues (Strip-mulch) and slightly graded hedgerows were very effective in terms of erosion control giving a soil loss of 1.99 and 1.28 t $ha^{-1}$, respectively, compared to 11.73 t $ha^{-1}$ for shifting cultivation and 12.42 t $ha^{-1}$ for plowed land (Dharmesena, 1994).

Alley cropping is an agroforestry system in which annual crops are grown between rows of leguminous trees. These trees are pruned during the cropping season and the prunings applied to the soil as mulch or incorporated as green manure (Kang *et al.*, 1984). During periods where no crops are grown, the trees are allowed to grow freely. Hedgerows of *Leucaena* in alley cropping form barriers that reduce soil erosion, while application of their prunings to the soil are believed to increase yields through recycling of plant nutrients and added nitrogen. In Haiti, the use of hedgerows to reduce soil loss from cropland is increasing in some regions, thanks to the efforts of the implementing organizations of the Productive Land Use Systems (PLUS) Project, formerly Agroforestry II (AF II), as well as other projects.

The major adverse effect of soil erosion is lowering of soil fertility. The potential of agroforestry to reduce or eliminate this decline in soil fertility is at least as important as that of controlling erosion (Nair, 1987, cited in Banda *et al.*, 1994; Young, 1989, cited in Tilander, 1993).

**Benefits of Alley Cropping**

Alley cropping has been shown to provide slow and continuous release of nutrients (Budelman, 1988) and to increase P availability (Haggar *et al.*, 1991, cited in Tilander, 1993), sustain soil productivity by maintaining soil organic matter, improve moisture

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# MATERIALS AND METHODS

The trial was conducted at Bois Greffin, Pernier, approximately 10 km east of Pétion Ville. Annual rainfall recorded over a four-year-period averaged 1324 mm. The rainfall pattern is bimodal with rains occurring from March until mid June and from late August through November. The two seasons are separated by a short dry spell from late June to mid August and a longer dry season lasting from late November to early March. This rainfall distribution pattern permits two maize crops a year. The elevation is about 240 m above sea level and the mean annual temperature, 27.5° C. The soil is a fine, mixed isohyperthermic Lithic Eutropept (Guthrie *et al.*, 1995). It is derived from limestone parent material, has a dark brown gravelly clay loam surface horizon with pH = 8.0 over a dusky red clay B horizon. Depth to bedrock varies but is generally shallow. The site has a north-facing slope of 30 % with stone walls resulting in terraces of 17-21 % slopes. Based upon rainfall records, the site may be considered intermediate in terms of the range in rainfall conditions within which alley cropping is expected to be practiced in Haiti.

In past years, maize (*Zea mays*), cassava (*Manihot esculenta*) and pigeon pea (*Cajanus cajan*) were planted in the first rainy season followed by carrots (*Daucus carota*) and sweet potato (*Ipomea batatas*) in the second season (Appendix Table A1). During the last three years prior to establishing the trial, carrots and lima bean were planted in the second season following a pasture fallow in first season.

### Site Preparation

Land clearing was carried out during March and April 1991. The plots of 8.0 m up and down hill and 7.5 m along contour were laid out in the field in late April 1991. Care was taken to avoid outcroppings or very shallow soil within the main plot area, particularly the harvest area. The upper limit of the plots were determined by the presence of a wall or outcropping. The lower limit was placed at least 1.5 m from the edge of the lower stone wall except for two plots where 1.0 m was allowed. Where not enough space was available, the wall was displaced and soil was filled in behind the new wall. Where no wall previously existed, a wall was built but no fill was added. Where large boulders were present within the plot, these were removed. In some plots where bedrock within 10 cm of the surface could not be avoided, the bedrock was chipped away to allow at least 20 cm of soil at the edges of the plots and considerably deeper in the harvested areas.

**Experimental Design**

The experiment was conducted on plots of 7.5 m long (along contour) by 8.0 m wide (along slope) using a randomized complete block design with three replications (Figure A1). The treatments were: control without structure (T1); contour canal (T2); alley cropping with hedgerows of *Leucaena leucocephala*, hereafter called *Leucaena* alone (T3); alley cropping with rows of *Panicum maximum,* hereafter called grass rows (T4); hedgerows of *L. leucocephala* and *P. maximum,* hereafter called *Leucaena* and grass (T5); stone wall (T6); alley cropping and fertilizer, hereafter called *Leucaena* and fertilizer (T7).

**Establishment of Conservation Structures**

The locations of conservation structures were marked out in each plot separately, using a line level to locate the structures along the contour. Two rows were spaced 8.0 m apart, determining at the same time the upper and lower borders of the plot. A third row was located between the other two, leaving an alley of 4 m in the upper and lower parts of the plot. Where the outside lines converged or diverged because of variations in slope, the upper and lower rows were adjusted to 4 m above and below the central row.

Land preparation in plots with *Leucaena* hedgerows was carried out in the first two weeks of May 1991. An width of about 30 cm was deep hoed with a pick and leveled with a rake.

*L. leucocephala* variety K636 was the species selected for the hedgerows. The seed was collected from the Operation Double Harvest site at Cazeau. Seed was scarified by cutting the rounded (cotyledon) with a razor blade. Seeding of *Leucaena* was done on May 16, 1991. Four seeds were planted per hill. Plants were spaced 0.1 m apart within row. The rows of 7.5 m long were spaced 4 m apart on contour. Seedlings were thinned to one per hill at approximately six weeks after planting. Because of drought following planting, the hedgerows were watered with a watering can or bucket on June 17 and June 25, 1991. Approximately 2.3 l of water were applied per linear meter of row at each irrigation.

*Panicum maximum* grass was collected at the same site and planted 4 m apart on contour in September 1991 in similar fashion as the hedgerows. For each row, a width of about 30 cm was deep hoed with a pick and leveled with a rake. Stem cuttings of approximately 15 cm long with two or three nodes were planted at 20 cm spacing within row. In treatment T5, the grass rows were planted 25 cm downhill from the *Leucaena* hedgerows.

The stone walls were laid out on contour in September 1991. Furrows were dug approximately 15 cm deep to form a foundation, and the walls were constructed to a height of approximately 25 cm above the soil level at a width of approximately 30 cm. No mortar was used, and the structure's strength was achieved by careful position of the rocks and giving a back-tilt of the structure to counter the effects of gravity.

The contour canals were established in mid-March 1993 after the first soil preparation prior to planting maize. Furrows of 30 cm wide (15 cm up and down of the corresponding line of hedgerow) were dug to a depth of approximately 25 cm. The soil from each canal was spread on both sides of the canal at the start of the first cropping season. In subsequent cropping seasons, the soil from the central and lower canals was redistributed respectively in the upper and lower parts of the plot.

### Hedgerow and Grass Management

The *Leucaena* hedgerows were approximately two years old at the start of the experiment. Hedgerows were pruned to 50 cm height, beginning approximately ten days before the first maize seeding. The prunings were applied as mulch in the inter-hedgerow spacings, or alleys. The first pruning took place between March 11 and March 17, 1993, on *Leucaena* hedgerows of approximately 4 m height. In subsequent cropping seasons, the first pruning was made a few days prior to planting maize. One more pruning was carried out thirty five days later, during the first two cropping seasons; two more prunings were done at approximately 30 and 60 days after the first pruning during the third and fourth cropping seasons.

The grass was pruned at ground level at each cut and the prunings were applied as mulch to the soil surface. During each cropping season, the first pruning took place approximately one day prior to planting maize. The pruning frequency used for grass species was the same of that used for *Leucaena* hedgerows.

### Maize Crop

Maize was seeded on March 24 and August 25, 1993, and on March 10 and August 27, 1994. Two maize crops a year were grown. March plantings were harvested in June or July (first rainy season, or Season A) and August plantings were harvested in December (second rainy season; Season B).

Approximately one month prior to the initial planting, the first soil preparation was made with hoe and pick and the plant residues left on the soil surface. In subsequent seasons, the first soil preparation took place approximately fifteen days before seeding of maize. A second soil preparation with a hoe was done on all plots approximately three days before maize planting. In alley plots, harvested leaves and green stem biomass, referred to as prunings, were returned to the soil surface as mulch. In subsequent seasons, residue from the previous maize crop was incorporated into the soil with the first soil preparation.

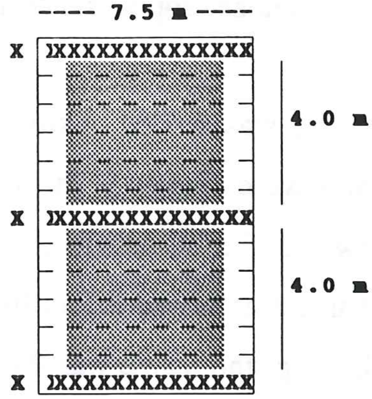
A local population of maize was seeded in rows spaced 80 cm apart and 40 cm within row. Eight rows of maize were planted in the alley plots with *Leucaena* or grass (4 in each alley) and ten rows in the stone wall, contour canal and control plots, respectively (Figure 1). The harvest area was 5.5 m by 8 m. Three seeds were planted per hill. Fifteen days after planting, the maize was thinned to one plant per hill, giving a population density of 25,000 plants $ha^{-1}$ in the alley cropped plots and 31,250 plants $ha^{-1}$ in the other plots. In Treatment T7, 250 kg of a 15-15-15 compound fertilizer was applied to the maize in hill at planting, giving approximately 37.5 kg N, 37.5 kg $P_2O_5$ and 37.5 kg $K_2O$ $ha^{-1}$.

Weeds were controlled by means of machetes. A first weeding was carried out thirty days after planting and a second took place at approximately three weeks after. The maize was grown during season A and season B for two consecutive years.

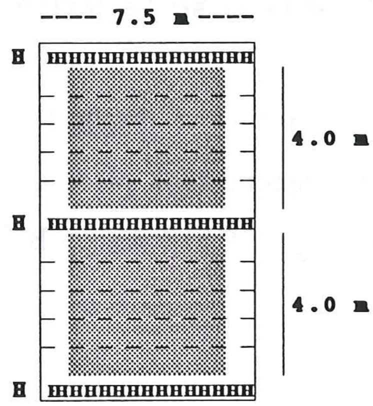
**Observations**

During the cropping season, maize plants were counted after thinning and at harvest. Data recorded at harvest were: Grain yield in t $ha^{-1}$, calculated at 13% moisture, lodging, determined as % total plants lodged in each plot, number of ears harvested, number of fertile plants per harvest area, maize height, fresh weight of ears and % moisture of harvested grains, determined by means of a grain moisture tester.

At harvest of hedgerows, prunings were divided into leaves, green stems < 1 cm in diameter, stems 1-5 cm in diameter, stems > 5 cm in diameter and pods. Fresh weight of each component was determined separately in the field. Samples of fresh biomass of each component and leaves of *P. maximum* grass were oven-dried at 71.0° C




*X = Stone Walls or Contour Canal*




*H = Leucaena Hedgerows or Grass Rows*

– – – – – = Maize rows
Area shaded = Harvested Plot

Figure 1. Treatments layout in Agroforestry Adaptive Trial 3.

for dry matter determination. However, analysis of variance was calculated for the total of cuts made during each cropping season. Statistical analyses were conducted using the Statistical Analysis System (SAS).

# RESULTS

## RAINFALL CONDITIONS

Total measured rainfall for each cropping season, beginning approximately ten days before maize seeding, was 551.0 mm, 493.8 mm, 756.0 mm and 797.6 mm in the first four cropping seasons, respectively (Figure 2). The first and third cropping seasons are referred to as season A while the second and fourth cropping are referred to as season B. Rainfall was generally erratic during one or more stages of crop development in each cropping season. However, except for the second cropping season, more than 50 % of the total rainfall recorded fell between late vegetative stage and late flowering stage (Figure 2). In the first cropping season, drought stress occurred during almost the entire vegetative stage and during the grain-filling period. During the second cropping season, drought stress occurred at the start of the flowering stage and again during the grain-filling period. In the third cropping season, drought stress occurred after flowering and continued until maturity. In the fourth cropping season, drought stress occurred during part of vegetative stage and again during the final stage of grain filing (Figure 2).

## MAIZE CROP

### Grain Yield

The maize grain yield in the first four cropping seasons is presented in Table 1. There were significant differences in yield among treatments in each season. During the first two seasons, maize yields were highest in the stone wall and control treatments with 1.56 and 1.52 t $ha^{-1}$ in the first season and 1.06 and 1.16 t $ha^{-1}$ in the second cropping

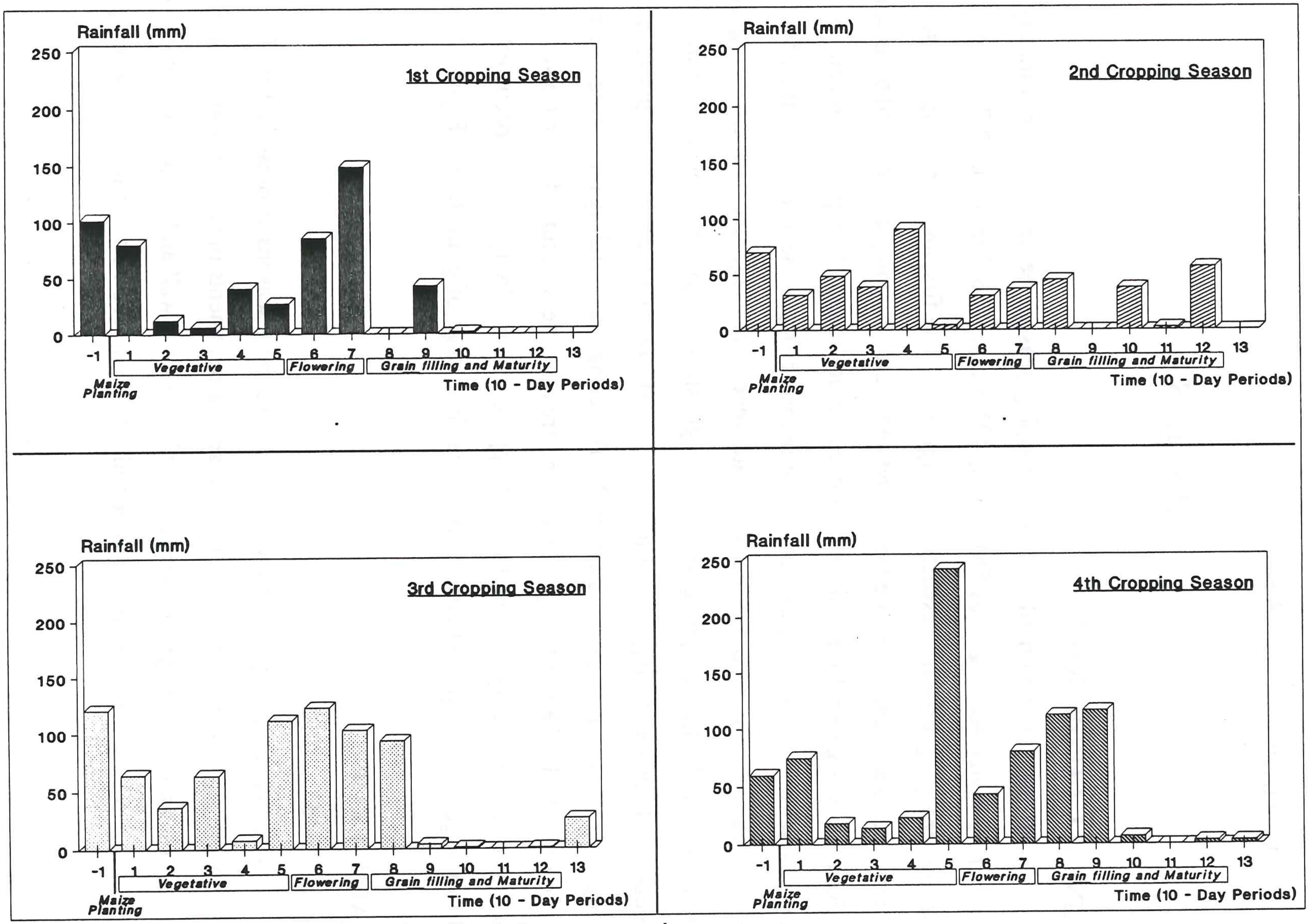



Figure 2. Rainfall during the first four cropping seasons

season, respectively. These two treatments were followed by the contour canals in the first season and by hedgerows with fertilizer and contour canals in the second season. The least productive treatment was hedgerows alone, giving 0.54 and 0.52 t ha$^{-1}$, respectively, during the first and second cropping seasons (Table 1).

**Table 1. Maize grain yield at 13 % moisture in first four cropping seasons. Agroforestry Adaptive Trial III.**

| Treatments | Cropping Seasons[¶] | | | |
|---|---|---|---|---|
| | 1st | 2nd | 3rd | 4th |
| | t/ha | | | |
| Hedgerow[†] and Fertilizer | 0.89 | 0.99 | 1.25 | 0.93 |
| Hedgerow and Grass | 0.66 | 0.65 | 0.77 | 0.82 |
| Hedgerow alone | 0.54 | 0.52 | 0.61 | 0.69 |
| Stone wall | 1.56 | 1.06 | 0.99 | 0.54 |
| Control (No Structure) | 1.52 | 1.16 | 0.94 | 0.49 |
| Grass[‡] row | 1.06 | 0.74 | 0.69 | 0.47 |
| Contour Canal | 1.37 | 0.98 | 0.83 | 0.46 |
| Significance (F test) | * | * | * | *** |
| $LSD_{.05}$ | 0.58 | 0.35 | 0.37 | 0.23 |
| CV % | 30.05 | 22.65 | 23.75 | 20.74 |

¶/ 1st = First rainy season, 24 March - 15 July, 1993; 2nd = Second rainy season, 25 August - 15 December, 1993; 3rd = First rainy season, 9 March - 7 July, 1994; 4th = Second rainy season, 26 August 94 - 3 January, 1995; †/ Hedgerows of *L. leucocephala*, ‡/ Rows of *Panicum maximum*
*, *** = Significant at the 5 % and 0.5 % levels of probability, respectively.

In the third and fourth seasons, hedgerows with fertilizer ranked highest for maize yield, giving 1.25 and 0.93 t ha$^{-1}$, respectively (Table 1). This was followed by stone walls in the third season and by hedgerows with grass in the fourth cropping season, with no significant differences among them. In the third cropping season, plots with *Leucaena* hedgerows alone were the least productive (0.61 t ha$^{-1}$) while in the fourth cropping season, the lowest maize yield was obtained from contour canals (0.46 t $ha^{-1}$).

### Time Trends

The trend over time has been a slight increase in maize grain yield in all alley plots with *L. leucocephala* (Figure 3), although in the fourth cropping season a yield decline appears to have occurred in fertilized alley plots. On the other hand, maize yields decreased over time in control treatment and in all plots with soil conservation practices other than *Leucaena* hedgerows (Table 1 and Fig. 3).

During the first cropping season, the overall average maize yield for the control and plots with other soil conservation practices was 98 % higher than that of alley plots with *Leucaena* hedgerows, whereas in the fourth cropping season maize yield in the control and plots with other soil conservation practices was 40 % less than that of the same alley plots with *Leucaena* (Table 1 and Fig. 3).

## HEDGEROW BIOMASS PRODUCTION

Biomass data presented in this section are season totals from two prunings during the first two cropping seasons and three prunings during the third and fourth seasons. Biomass fresh weight in all four seasons, wood and pod biomass production in the first season and biomass production obtained at each individual pruning are presented in Appendix Tables A6 - A11.

### Total and Leaf Biomass

Total biomass is an indication of the overall productivity of the hedgerows. Significant differences in total biomass were observed among treatments in all four seasons (Table 2). The hedgerow with grass treatment produced significantly more total biomass than other alley plots. This was followed by hedgerow and fertilizer treatment which is, in terms of statistical significance, similar to the treatment of hedgerow alone

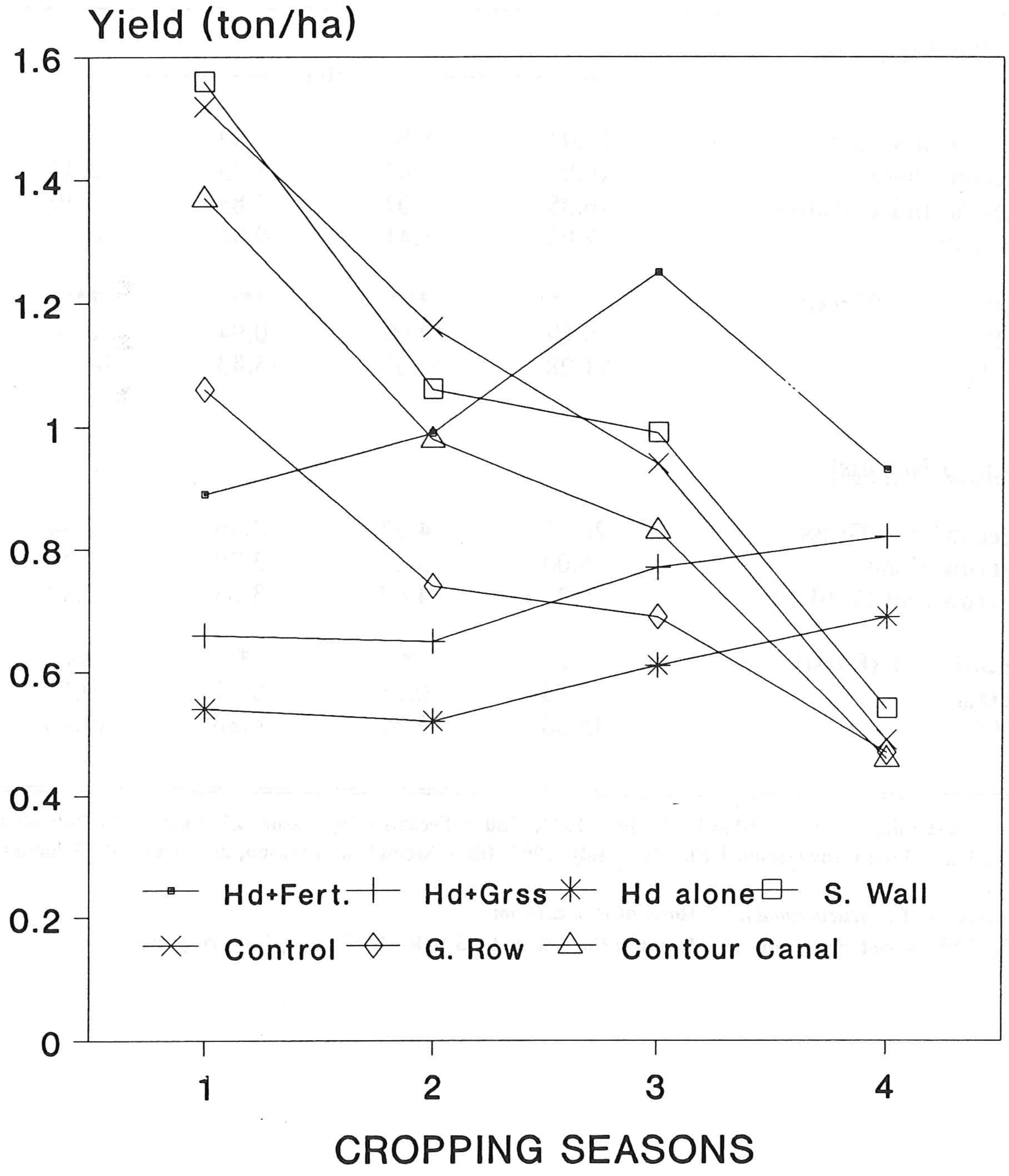



Fig.3. Effect of Alley cropping and other soil consrvation practices on maize yields.in first four cropping seasons

**Table 2. Total dry weight biomass harvested from hedgerows in first four cropping seasons. Agroforestry Adaptive Trial III.**

| Treatments | Cropping Seasons[¶] 1st | 2nd | 3rd | 4th |
|---|---|---|---|---|
| *(Leucaena and Grass)* | t/ha | | | |
| Hedgerow[†] and Grass | 21.02 | 4.54 | 4.09 | 2.99 |
| Hedgerow alone | 16.00 | 3.83 | 3.39 | 2.42 |
| Hedgerow and Fertilizer | 16.35 | 4.07 | 3.83 | 2.49 |
| Grass[‡] row | 2.03 | 1.41 | 0.94 | 0.62 |
| Significance (F test) | *** | *** | *** | *** |
| $LSD_{.05}$ | 5.89 | 0.99 | 0.94 | 0.60 |
| CV % | 21.28 | 14.32 | 15.43 | 14.21 |
| *(Leucaena biomass)* | | | | |
| Hedgerow[†] and Grass | 20.61 | 4.37 | 3.96 | 2.74 |
| Hedgerow alone | 16.00 | 3.83 | 3.39 | 2.42 |
| Hedgerow and Fertilizer | 16.35 | 4.07 | 3.83 | 2.49 |
| Significance (F test) | ns | * | * | ns |
| $LSD_{.05}$ | 6.23 | 0.31 | 0.41 | 0.60 |
| CV % | 15.58 | 3.31 | 4.86 | 10.46 |

¶/ 1st = First rainy season, 24 March - 15 July, 1993; 2nd = Second rainy season, 25 August - 15 December, 1993; 3rd = First rainy season, 9 March - 7 July, 1994; 4th = Second rainy season, 26 August 94 - 3 January, 1995;

†/ Hedgerows of *L. leucocephala*, ‡/ Rows of *P. maximum*

ns, *, *** = Not significant, significant at the 5 % and 0.5 % levels of probability, respectively.

in all seasons. The grass rows produced the least biomass in all four seasons.

Total *Leucaena* biomass (grass excluded) was highest in the hedgerow with grass treatment, followed by hedgerows with fertilizer. However, differences were statistically significant only during the second and third cropping seasons. The grass row appears to have positively influenced the production of *Leucaena* hedgerows whereas application of fertilizer did not appear to have any effect on the production of *Leucaena* hedgerows (Table 2).

Leaves are the most important component of hedgerow biomass for alley cropping. They decompose rapidly and the nutrients they contain are most readily available to the crop. With grass included, there were significant differences in leaf dry weight biomass in the last two cropping seasons (Table 3). As with total biomass, alley plots with hedgerow and grass produced more leaf biomass than other treatments. When only biomass from *Leucaena* leaves are considered, the hedgerow with grass still ranked highest, but differences were not significant.

The association of *Leucaena* hedgerows with grass appears to have had a depressing effect on the grass (Table 3). The lack of statistical significance is due to the low precision of the test. However, the grass associated with *Leucaena* hedgerows appeared to increase in production in the fourth season, compared to the previous two seasons, whereas a decline in biomass production was observed for the grass rows grown alone.

**Time Trends**

Highest total biomass was produced during the first cropping season for *Leucaena* hedgerows (Table 2). These yields were high because the *Leucaena* trees were approximately two years old and had not previously been pruned. Most of the production in the first season was stem biomass of 1-5 cm diameter (Table 4). Ignoring the first season, a decline in total and leaf biomass yields seems to have occurred over the seasons

Table 3. **Leaf dry weight biomass harvested from hedgerows in first four cropping seasons. Agroforestry Adaptive Trial III.**

| Treatments | Cropping Seasons[¶] 1st | 2nd | 3rd | 4th |
|---|---|---|---|---|
| (Leucaena and Grass) | | t/ha | | |
| Hedgerow[†] and Grass | 3.81 | 2.35 | 2.23 | 2.00 |
| Hedgerow alone | 3.27 | 1.89 | 1.82 | 1.54 |
| Hedgerow and Fertilizer | 3.19 | 2.10 | 2.01 | 1.63 |
| Grass[‡] row | 2.03 | 1.41 | 0.94 | 0.62 |
| Significance (F test) | ns | ns | * | *** |
| $LSD_{.05}$ | 1.69 | 0.80 | 0.74 | 0.49 |
| CV % | 27.54 | 20.56 | 21.21 | 16.95 |
| (Leucaena biomass) | | | | |
| Hedgerow[†] and Grass | 3.40 | 2.18 | 2.10 | 1.75 |
| Hedgerow alone | 3.27 | 1.89 | 1.82 | 1.54 |
| Hedgerow and Fertilizer | 3.19 | 2.10 | 2.01 | 1.63 |
| Significance (F test) | ns | ns | ns | ns |
| $LSD_{.05}$ | 0.83 | 0.36 | 0.35 | 0.51 |
| CV % | 11.15 | 7.78 | 7.88 | 13.71 |
| (Grass leaves) | | | | |
| Hedgerow[†] and Grass | 0.41 | 0.16 | 0.13 | 0.25 |
| Grass[‡] row | 2.03 | 1.41 | 0.94 | 0.62 |
| Significance (F test) | ns | ns | ns | ns |
| $LSD_{.05}$ | 3.26 | 1.34 | 1.11 | 0.68 |
| CV % | 75.95 | 48.68 | 59.08 | 44.39 |

¶/ 1st = First rainy season, 24 March - 15 July, 1993; 2nd = Second rainy season, 25 August - 15 December, 1993; 3rd = First rainy season, 9 March - 7 July, 1994; 4th = Second rainy season, 26 August 94 - 3 January, 1995;

†/ Hedgerows of *L. leucocephala*, ‡/ Rows of *P. maximum*

ns, *, *** = Not significant, significant at the 5 % and 0.5 % levels of probability, respectively.

Table 4. Branch and stem dry weight biomass (t/ha) harvested from hedgerows in first four cropping seasons. Agroforestry Adaptive Trial III.

| Treatments | 1st | 2nd | 3rd | 4th |
|---|---|---|---|---|
| | Branches[$] / Seasons[¶] | | | |
| Hedgerow[†] and Grass | 3.54 | 1.57 | 1.03 | 0.80 |
| Hedgerow alone | 2.60 | 1.48 | 0.96 | 0.74 |
| Hedgerow and Fertilizer | 2.61 | 1.48 | 1.09 | 0.73 |
| Significance (F test) | ns | ns | ns | ns |
| $LSD_{.05}$ | 1.10 | 0.22 | 0.14 | 0.26 |
| CV % | 16.61 | 6.50 | 5.89 | 15.14 |
| | Stems[††] / Seasons | | | |
| Hedgerow and Grass | 12.90 | 0.62 | 0.83 | 0.19 |
| Hedgerow alone | 9.94 | 0.46 | 0.60 | 0.14 |
| Hedgerow and Fertilizer | 10.31 | 0.49 | 0.74 | 0.13 |
| Significance (F test) | ns | * | ns | ns |
| $LSD_{.05}$ | 4.38 | 0.08 | 0.35 | 0.09 |
| CV % | 17.48 | 6.85 | 21.69 | 25.29 |

¶/ 1st = First rainy season, 24 March - 15 July, 1993; 2nd = Second rainy season, 25 August - 15 December, 1993; 3rd = First rainy season, 9 March - 7 July, 1994; 4th = Second rainy season, 26 August 94 - 3 January, 1995;

†/ Hedgerows of *L. leucocephala*, $/ Branches = Green Stems < 1 cm (diameter) ††/ Stems 1-5 cm (diameter)

ns, * = Not significant, significant at the 5 % level of probability, respectively.

(Tables 2 and 3). This may be partially caused by an increased frequency of pruning in the second year of the trial. The yield decline in the fourth season appears to have been most pronounced in fertilized *Leucaena* plots.

Cumulative total and leaf dry weight biomass production (Figures 4 and 5) give an important overview of hedgerow productivity. Highest cumulative total and leaf biomass yields was obtained in the hedgerow with grass treatment, while the least cumulative biomass was produced by grass rows. For total biomass, the differences among treatments appear to be stable over the cropping seasons (Figure 4) whereas for cumulative leaf dry matter (Figure 5) a more pronounced difference between the hedgerow with grass treatment and other treatments seems to be evident from the second cropping season.

**Branch and Stem Biomass**

Small green stems, herein referred to as branches, and woody stems are other components of biomass production. The small green stems are secondary in value as a nutrient source, being slower in decomposition than leaves and lower in nitrogen (N) content. The larger woody stems decompose slowly, and because of high proportion of carbon to N, tie up N, making it less available to plants. However, the larger stems have value in reinforcing the hedgerows as barriers to erosion and as secondary products, such as fuel or stakes.

The hedgerow with grass treatment produced the most branch biomass in three of the four seasons while it produced more stem biomass in all four cropping seasons. However differences in branch biomass production were not significant (Table 4). For stem biomass, significant differences ($P < 0.05$) among treatments were obtained in the second season. The treatments of hedgerow alone and hedgerow with fertilizer did not differ statistically in branch and stem biomass.

A decline in branch biomass production seems to have occurred from the second

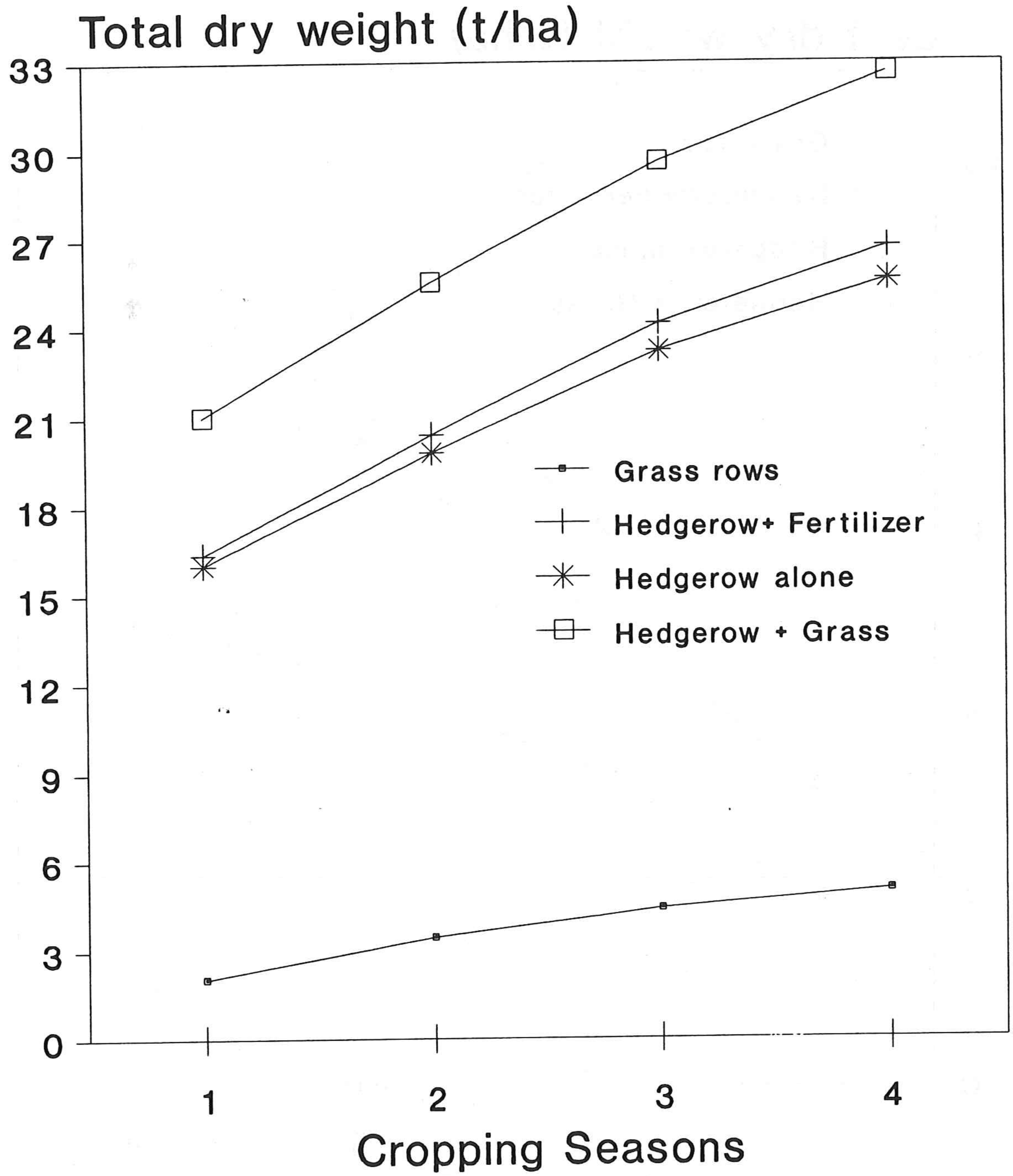



Figure 4. Cumulative total dry matter production by Leucaena hedgerows and grass rows.

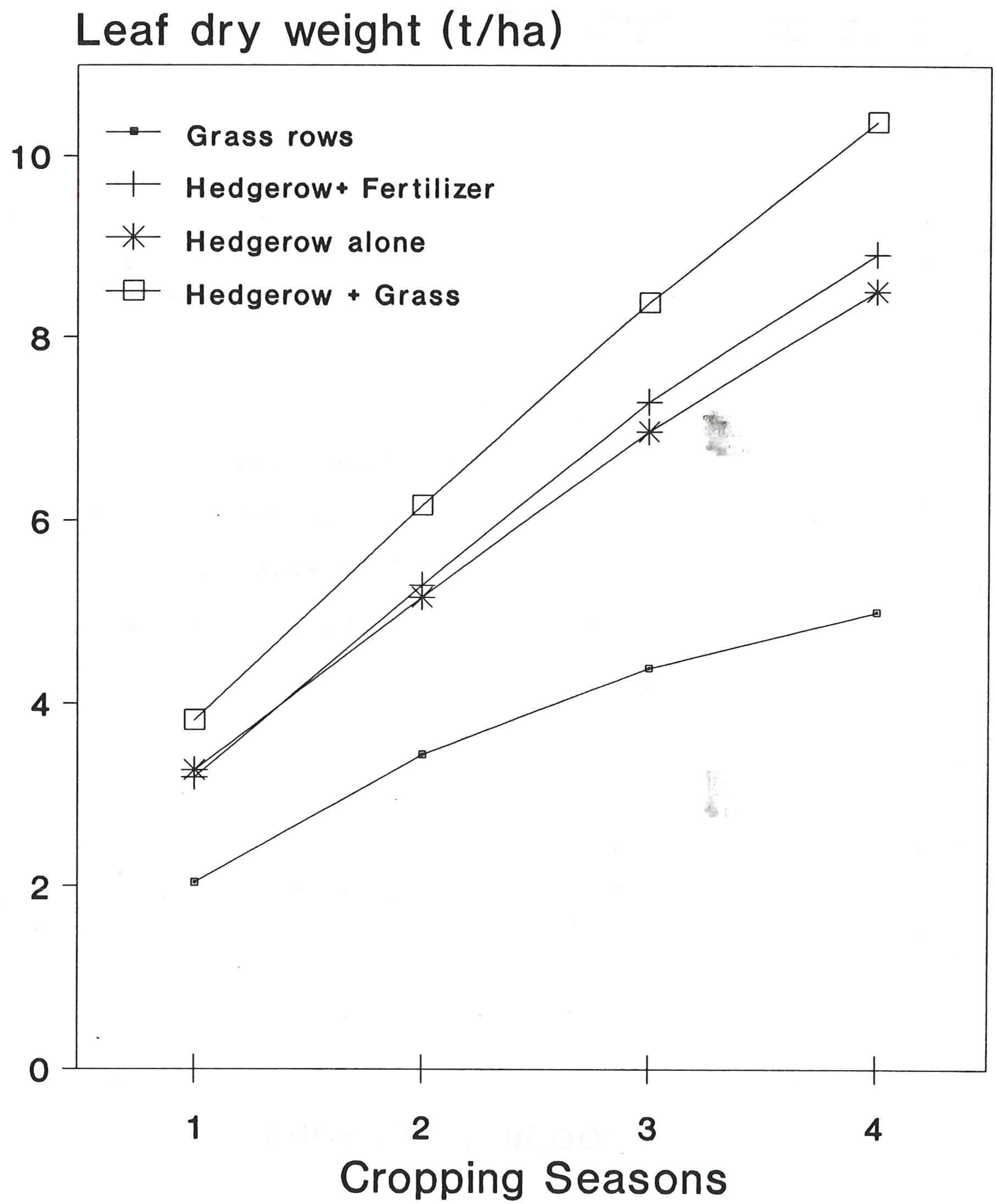



Figure 5. Cumulative leaf dry matter production by Leucaena hedgerows and grass rows.

cropping season whereas for stems, although a general decline was evident, an increase was obtained in the third season followed by a drop in the fourth season (Table 4).

# DISCUSSION

## MAIZE CROP

### Alley Cropping vs other Soil Conservation Practices

A consistent decline in yield over time was observed in the control (no soil conservation structure) and in plots with soil conservation structures that did not include *Leucaena*. Yields remained stable or increased slightly over time in alley cropping plots with *Leucaena*. During the first cropping season, the maize yield in the control, stone wall and contour canal treatments were 43 %, 47 % and 29 % superior, respectively, to that of the next most productive treatment, grass rows, and 181 %, 189 % and 154 % higher than that of Hedgerows alone, the least productive treatment (Figure 6). In the fourth season, those same treatments yielded 47 %, 42 % and 51 % less, respectively, than the most productive hedgerow treatment (hedgerow with fertilizer) and 40 %, 34 % and 44 % less than the hedgerow with grass treatment (Figure 6).

The average yield for alley cropping treatments was 47 %, 32 % and 10 % lower than the average of treatments without vegetative structures (control, stone wall and contour canal) during the first, second and third cropping seasons, respectively, whereas in the fourth cropping season, maize yield in alley cropped plots was 46.5 % higher than that of treatments without vegetative structures. The increased pruning frequency in the fourth season, combined with high rainfall are likely factors responsible for high yields in alley cropping treatments. Average yield losses over the four seasons were 0.34, 0.34, 0.20 and 0.30 t $ha^{-1}$ $season^{-1}$ for the stone wall, control, grass rows and contour canal treatments, respectively, whereas yield increased over time in alley plots with *Leucaena*

1=Control 2=Contour Canal 3=Hedgerow alone 4=Grass Rows
5=Hedgerow and Grass 6=Stone Wall 7=Hedgerow and Fertilizer

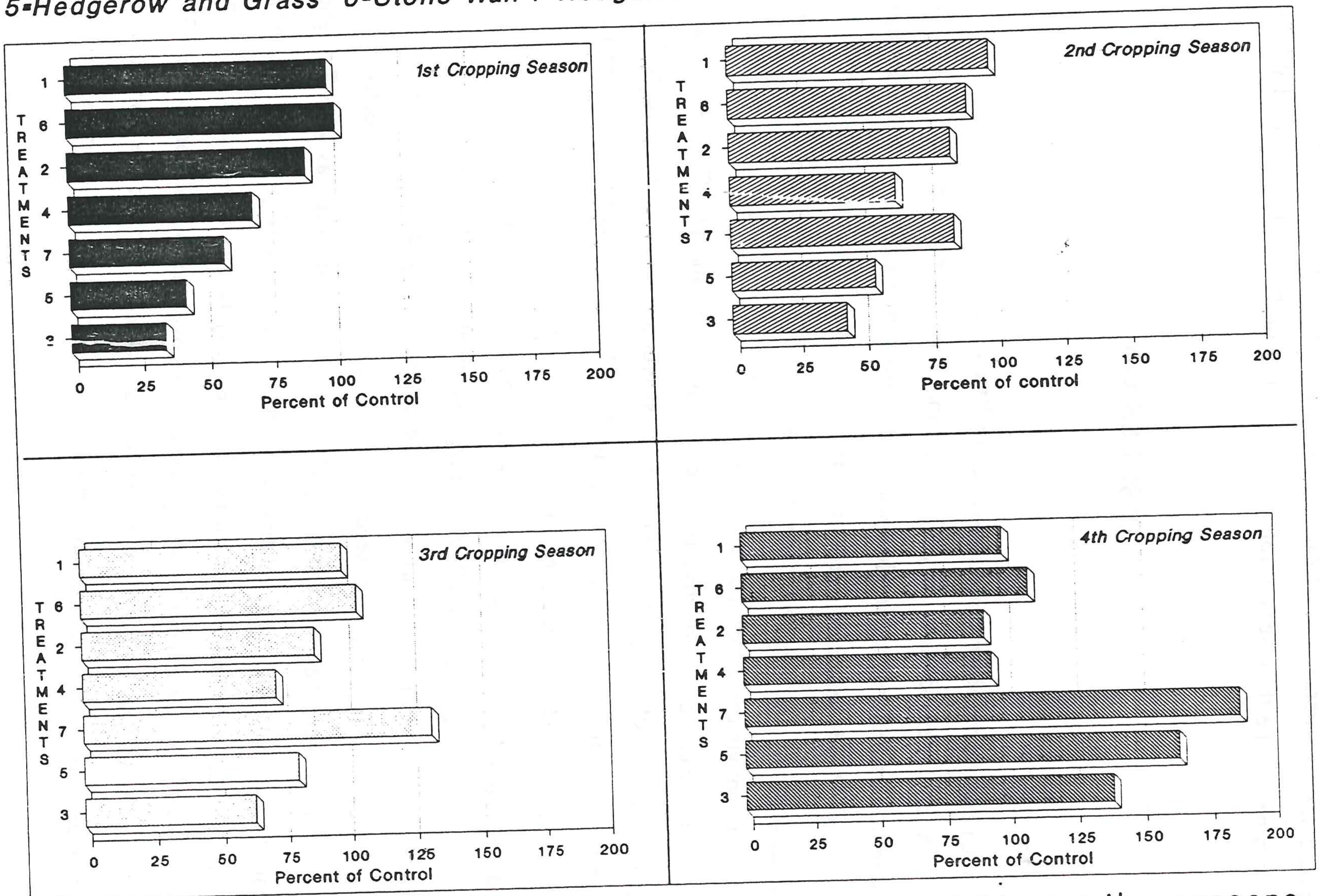



Figure 6. Effect of Alley cropping on improving maize yield over the seasons

hedgerows.

The increase in maize yield over the seasons in alley cropping plots with *Leucaena* may be attributed to added nitrogen applied in the prunings and possibly to improved soil moisture retention. The combined dry weight of leaves and green stems applied to the alleys was estimated at 11.27 (of which 0.57 was grass), 9.24 and 9.38 t $ha^{-1}$ in the first year for hedgerow with grass, hedgerow alone and hedgerow with fertilizer treatments, respectively, and 6.06 (of which 0.38 was grass), 5.06 and 5.46 t $ha^{-1}$ in the second year. Assuming a moderate concentration of N in leaves and twigs of 3.33 % (Kang, 1993), these three treatments would have provided, respectively, 356, 307 and 312 Kg N $ha^{-1}$ during the first year of maize cropping and 189, 168 and 182 Kg N $ha^{-1}$ in the second year.

Similar results are emerging from other studies elsewhere. Tonye and Titi-Nwel (1995) reported a decline in maize grain yields from 1.2 t $ha^{-1}$ in the first year of cropping to 0.8 t $ha^{-1}$ in the third year for the treeless (control) plot whereas, with the application of Leucaena prunings alone, maize yield stabilized at 2.5 t $ha^{-1}$ during the second and third year of cropping. Banda et *al*. (1994) found that maize yields were maintained at 1.5 - 2.0 t $ha^{-1}$ on the protected plots compared with a progressive decline from 0.8 to 0.5 t $ha^{-1}$ on the sole maize crop after six years of cropping. Isaac *et al* (1995) observed a decline over time in a stone wall control treatment while maize yield remained steady in the best alley cropping treatments. However, these results differ from those obtained by Lal (1989b) who reported over a six year period 10 % lower maize grain yield from alley cropping than that of control.

The higher yield in the control and in the stone wall and contour canal treatments during the first two cropping seasons may be attributed in part to a 20 % higher maize population in these plots and to residual effects of two year fallow period during which shrubs and weeds were cut regularly and left on the soil surface without disturbing the soil. These residues probably supplied nutrients that might otherwise have not been available in these treatments. In plots with *Leucaena,* competition for light due to partial shading of the maize by the hedgerows, combined with scarce moisture during the vegetative stage in the first season and erratic rainfall in the second season (Figure 2) may have also negated the beneficial effects of pruning application during the first two seasons. The pruning regime was modified in the second year to minimize these effects. These observations are in accordance with those obtained by Isaac et *al.* (1995), who reported higher yields with the stone wall control than with alley cropping during the first year of the experiment. Similarly, over two growing seasons, Chirwa et *al.* (1994) observed a reduction in maize grain yield with *Leucaena* prunings alone as compared to an unfertilized maize grown as a sole crop.

The yield decline in the control, stone wall and contour canal treatments may be the results of soil degradation and nutrient depletion due to continuous cropping. Stand losses in the fourth season were also greater in these treatments. In plots with stone wall or contour canal, yields dropped at slower rate than that of the control treatment. These observations imply that although the soil conservation practices other than alley cropping were effective in reducing soil loss (not reported), without measures taken to counteract the effect of removal of nutrients by cultivation, yield may be reduced.

The *Panicum* grass treatment ranked lower in maize yield than the control, stone wall and contour canal treatments during the first three cropping seasons and gave similar yields in the fourth season. In addition to a 20 % lower maize population, competition for water and nutrients, especially nitrogen, by the grass rows were likely to reduce the maize yields in this *Panicum* grass treatment. Since grass is an important livestock feed and was effective in reducing soil loss (not reported), grass rows may be viable in some regions.

### Comparisons Among Alley Cropping Treatments

During the first season, the maize grain production in alleys of *Panicum* grass was

19 %, 61 %, and 96 % higher than in the hedgerow with fertilizer, hedgerow with grass and hedgerow alone treatments, respectively (Table 1 and Figure 6). The superior performance of the grass row treatment in the first cropping season may be the result of less competition for light and possibly for water between the maize and the *Panicum* grass than between the maize and *Leucaena* hedgerows. From the second season, yield declined steadily in the grass row treatment while yield increased over time in alleys of *Leucaena*. In season 4, maize yields in the three *Leucaena* treatments (hedgerow with fertilizer, hedgerow with grass, hedgerow alone) were 98 %, 74 % and 47 % higher, respectively, than in the grass treatment (Figure 6). This was probably due to the large amount of *Leucaena* prunings applied. It is unlikely that the amount of biomass produced by *P. maximum* was adequate to provide the nutrients and organic matter needed to overcome the effects of grass competition and continuous cropping. Thus, although the grass rows were as effective as *Leucaena* hedgerows in controlling soil erosion, they did not have a beneficial effect on crop productivity.

Fertilizer application increased maize yield in each cropping season. The combination of alley cropping with fertilizer resulted in an average of 72 % and 40 % higher yield, respectively, than hedgerows alone or hedgerows with grass (Table 1). The hedgerow with grass treatment gave on average 23 % more maize grain than hedgerows alone. This may be due to more biomass applied to the soil surface, and the greater efficiency of the hedgerow and grass treatment in reducing soil loss. The most pronounced effect of fertilizer was in the third season, when hedgerows with fertilizer yielded 105 % and 62 % more than hedgerows alone and hedgerow with grass, respectively. The decline in maize yield in the season 4 in the hedgerows with fertilizer treatment may be attributed in part to a decreased response to fertilizer due to inadequate rainfall (Figure 2) and a severe insect attack during the vegetative stage of maize.

The response to fertilizer in alley cropping is consistent with experiences in Africa. In Zambia, application of 200 Kg $ha^{-1}$ diammonium phosphate at planting followed by split applications of 150 Kg urea $ha^{-1}$ to alleys of *Leucaena* doubled maize yields compared to unfertilized alleys with hedgerow prunings added to the plots (Chirwa *et al.*, 1994) . In Zaire, the combination of fertilizer and alley cropping with *Leucaena* resulted in higher maize yields than alley cropping without fertilizer in each of eight seasons (Shannon *et al.*, 1994). Application of 200 and 400 Kg $ha^{-1}$ of 20-10-10 **$N_2$-$P_2O_5$-$K_2O$** increased maize yield by a three-year average of 0.4 and 0.7 t $ha^{-1}$, respectively, compared to *Leucaena* prunings alone (Tonye and Titi-Nwel, 1995). Probably the N, P and K in fertilizer was more readily available to the crop than nutrients in the prunings, which take some time before they are decomposed. Also, the P contained in the prunings may have been inadequate to overcome P deficiency in the soil. Hence the combination of low rates of fertilizer with alley cropping may be the optimum solution to sustainable, economic increases in crop yield.

## OTHER MEASUREMENTS ON MAIZE

Trends for fresh ear weight and number of ears harvested were similar to that observed with grain yield (Appendix II). During the first two seasons, the control, stone wall, contour canal and *Panicum* grass treatments gave excellent results while in alley cropped plots with *Leucaena*, ear fresh weight and number of ears were depressed. In the fourth cropping season, the improved maize performance in alley cropping treatments with or without fertilizer may result from *Leucaena* mulch, which provides nitrogen and probably improves soil moisture content. Also, alley cropping with *Leucaena* increased % fertile plants, maize height and decreased stand loss over the cropping seasons.

## HEDGEROW BIOMASS YIELD

### Comparisons Among Treatments

Biomass production by *Leucaena* hedgerows was superior to that of *Panicum* grass in all four seasons. Combining the *Leucaena* with *Panicum* grass consistently resulted in highest yields for total and leaf biomass. Since the total production of the *Panicum* grass treatment was considered as leaf biomass, total and leaf biomass were the same. Thus, the difference between the *Panicum* grass and the *Leucaena* hedgerows treatments is greater for total than for leaf biomass (Figures 4 and 5). Also, differences between the hedgerows with grass and other *Leucaena* treatments appear to be cumulative. The higher biomass yields of hedgerows with grass may be attributed in part to the efficiency of this structure in reducing soil loss and probably on increased soil moisture retention and more efficient use of space.

**Comparisons Among *Leucaena* Hedgerow Treatments**

The combination of *Leucaena* hedgerows with *Panicum* grass resulted in greatest biomass production in all four seasons, although differences did not test significant at the 5 % level (Tables 3 and 4). Addition of fertilizer also showed a slight but non-significant increase in biomass yield. Shannon *et al.* (1994) reported that fertilizer application had no significant effect on biomass production over a four-year period while Dalland *et al.* (1993) observed a decline in *Leucaena* biomass production as the level of applied nitrogen fertilizer increased. Fertilizer application benefits primarily the maize crop and not the hedgerow.

The amounts of leaves and green stems totaled over four seasons were 16.4, 14.3 and 14.8 t dry matter $ha^{-1}$ for hedgerows with grass, hedgerows alone and hedgerows with fertilizer, respectively. By considering the first six months after *Leucaena* planting as establishment phase, the average yearly production of leaves and green stems for the same treatments was 8.5, 7.4 and 7.5 t $ha^{-1}$, respectively in the first year and 5.7, 5.1 and 5.5 t $ha^{-1}$, respectively during the second year. The lower production of leaves and green stems in the second year is because the *Leucaena* hedgerows were already two years old at time of the first pruning. These yields were slightly higher than those reported by Isaac *et al.* (1995), when the most productive hedgerow pruning treatment gave 4.5 and

5.2 t $ha^{-1}$, respectively during the first and second year of the study and 5.0 t $ha^{-1}$ for the highest yielding treatment of *L. leucocephala* on a calcareous soil (Isaac *et al.*, 1994).

Average yearly leaf biomass production of these treatments was 4.5, 4.1 and 4.2 t $ha^{-1}$, respectively, during the first year and 3.9, 3.4 and 3.6 t $ha^{-1}$ in the second year. Excluding the first season, when most biomass was from stems, there was a slight decline in biomass production from the second cropping season. However, this may be associated with an increase in pruning frequency in the second season. Two prunings per season were made during the first year and three were during the second year of the experiment. Increased pruning frequency depresses biomass production of *Leucaena* hedgerows (Duguma *et al.*, 1988; Isaac *et al.*, 1995). Similar declines in biomass production were reported by Isaac *et al.* (1995), but Shannon *et al.* (1994) reported an increase in production over time. Shannon *et al.* began their trial with newly planted hedgerows while Isaac *et al.* began with two-year old hedgerows.

Appendix Tables A10 and A11 show the amount of prunings available at each harvest for application to the companion crop at different stages of its development. Although the hedgerow with grass treatment produced the most total biomass in each season, its ranking in terms of leaf and green stem yields at individual prunings was not consistent.

### Comparisons Between *Panicum* Grass Treatments

Combining *P. maximum* grass with *Leucaena* drastically reduced the yield of grass. Shading, rather than competition for soil moisture by *L. leucocephala,* was probably the factor most responsible for low grass yields. The slight increase in *Panicum* biomass production in the fourth season in hedgerow with grass treatment may be attributed, in part, to increased pruning of *Leucaena* hedgerows, which provided more light for the companion grass rows and to the high rainfall recorded during this season. Although the *Leucaena* hedgerows depressed biomass yields of *P. maximum,* when the two are combined, *P. maximum* can supplement the *Leucaena* as a livestock feed and reinforce the *Leucaena* hedgerows as barriers to erosion.

## CONCLUSIONS

These preliminary results are very promising and consistent with previous experiences elsewhere. Although alley cropping initially results in lower crop yields than do conventional practices, within two years and under proper managment, alley cropping out-yields conventional practices, despite the loss of land area to the hedgerows. Over time, yields with alley cropping remain the same or increase, while yields decline in absence of alley cropping.

This trial is unique, in that it compares alley cropping with a number of other soil conservation techniques currently in use in Haiti. Not only was alley cropping superior, in the fourth season, to the unprotected control, but it was also superior to rock walls, contour canals and grass rows. This is because rock walls and contour canals, while effectively reducing soil loss from the plots, do nothing to reduce other forms of soil degradation associated with cropping, specifically loss of nutrients, organic matter, soil structure and water holding capacity. Grasses supply some biomass to serve as mulch, much less than does *Leucaena*, but compete with crops for nitrogen and water. The decline in yield with all conservation practices, except for alley cropping with *Leucaena*, illustrate the inadequacy of these conservation practices to sustain crop yields on their own.

The system promoted by CARE in the Northwest, referred to as *rampe paille améliorée*, was not directly included in this trial, but is similar to the contour canal treatment, in which crop residues were buried in the canals. In this trial, there was no difference in maize yield between the control and contour canal treatments. In fact, yield in the contour canal treatment ranked consistently lower than in the control. Crop residues such as maize stover are generally low in nitrogen, decompose slowly, and may render soil nitrogen less available to the crop. The benefits of *rampe paille améliorée* in terms of fertility improvement are negligible, while the benefits in erosion control are short-lived.

Although alley cropping is beginning to catch on in Haiti, more commonly, *Leucaena* hedgerows are utilized as livestock feed and prunings are not applied to the soil. A similar treatment was not included in this trial, but we know from an associated trial (Isaac *et al.*, 1995) that the results are similar to those of other soil conservation practices. Unless nitrogen rich biomass is added to the soil, crop yields cannot be sustained.

The combination of leucaena hedgerows with grass rows appeared to have an advantage over hedgerows alone, both in terms of higher maize grain and higher hedgerow biomass yields. These differences were not significant at the 5 % level, but were consistent over the four seasons. More time is needed in order to fully understand the merits and potential drawback of combining grass rows with *Leucaena* hedgerows.

There is a common belief among development workers in Haiti that commercial fertilizers are not appropriate for low resource Haitian farmers, except in the vegetable growing area of Kenscoff. The large yield increases obtained with a low rate of fertilizer applied in conjunction with alley cropping suggest that this assumption should be questioned.

The large fertilizer response also raises a more basic issue. Since the biomass applied was a major source of nitrogen, was the effect of the fertilizer due primarily to nitrogen or was it due to phosphorus? High pH soils are known to "fix" phosphorus, i.e. render it unavailable to plants. Did application of large quantities of biomass to the calcareous soil increase the efficiency of phosphorus fertilizer use by the maize? This is a subject that merits study.

## Recommendations

- Alley cropping should receive priority in the extension programs of PADF and CARE. Advice should be provided on pruning methodology and on the importance of soil application of prunings.
- *Rampe Paille Amélioré* should not be promoted except in conjunction with other more long-term solutions to soil degradation, such as in conjunction with hedgerow establishment for alley cropping.
- Stone walls, contour canals and grass rows are useful in reducing soil erosion, but to provide maximum benefits to crops, should be combined with practices that enhance soil fertility.
- This trial should be continued for several more seasons to confirm trends observed in the third and fourth seasons. Of particular concern is the effect of dry and wet seasons on the relative maize yields with and without alley cropping. The long-term performance of the tree-grass combination should also be assessed.
- Additional research is justified on alley cropping and other conservation practices that return substantial amounts of nitrogen rich biomass to the soil.
- Economic analysis should be conducted on the effect of combining grass with *leucaena* hedgerows to determine if the apparent additional crop and biomass yields merit the additional costs of planting and maintaining the grass rows.
- Economic analysis should be conducted on the effect of fertilizer application in conjunction with soil conservation practices such as alley cropping. A simple cost-benefit analysis should be run on the fertilizer treatment in the present trial to determine if the returns to applied fertilizer are economic.
- The effect of organic applications on phosphorus fixation in calcareous soils should be studied.

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# APPENDIX I

## FIELD PLAN AND CROPPING HISTORY

Space between Structures : 4 m

Plot size : 7.5 m x 8 m

Distance between *Leucaena* plants : 10 cm

**TRAITEMENTS** :

1. Control, no structure
2. Contour Canal
3. Hedgerow alone
4. Grass row
5. Hedgerow and grass
6. Dry wall
7. Hedgerow and fertilizer

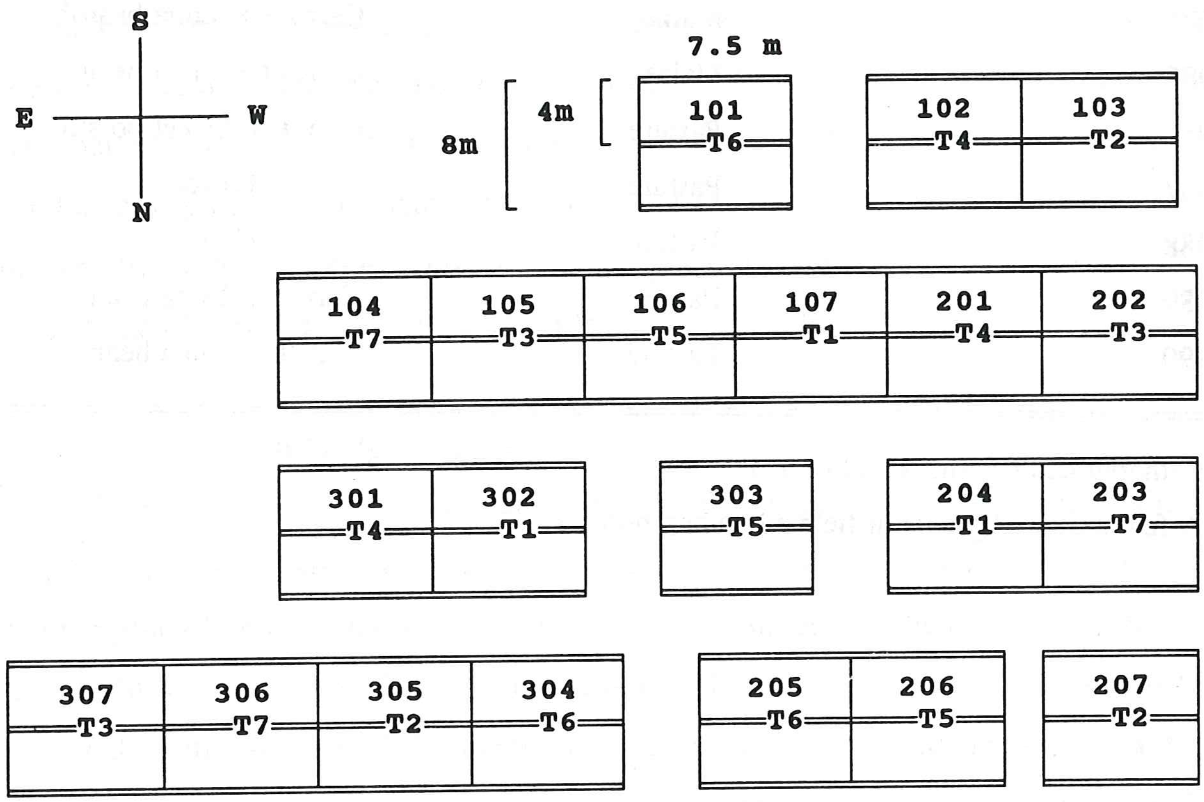


Figure A1. Plot layout at Pernier. Agroforestry Adaptive Trial 3.

Table A2. Weight and Number of ears harvested in first four cropping seasons. Agroforestry Adaptive Trial III.

| Treatments | Ear Weight/Seasons[¶] 1st | 2nd | 3rd | 4th |
|---|---|---|---|---|
| | t/ha | | | |
| Hedgerow[†] and Fertilizer | 1.08 | 1.34 | 1.49 | 1.13 |
| Hedgerow and Grass | 0.80 | 0.88 | 0.93 | 0.99 |
| Hedgerow alone | 0.67 | 0.69 | 0.72 | 0.86 |
| Stone wall | 1.86 | 1.43 | 1.19 | 0.67 |
| Control (No Structure) | 1.88 | 1.58 | 1.15 | 0.62 |
| Grass[‡] row | 1.33 | 0.99 | 0.83 | 0.60 |
| Contour Canal | 1.63 | 1.31 | 1.05 | 0.58 |
| Significance (F test) | ** | ** | * | *** |
| $LSD_{.05}$ | 0.66 | 0.45 | 0.43 | 0.27 |
| CV % | 28.09 | 21.31 | 23.10 | 19.47 |
| | # of Ears Harvested | | | |
| Hedgerow[†] and Fertilizer | 98.70 | 101.70 | 119.00 | 85.30 |
| Hedgerow and Grass | 91.30 | 94.00 | 96.00 | 79.00 |
| Hedgerow alone | 87.70 | 83.70 | 85.30 | 80.00 |
| Stone wall | 138.30 | 117.00 | 109.70 | 70.00 |
| Control (No Structure) | 125.00 | 116.70 | 111.30 | 66.70 |
| Grass[‡] row | 100.70 | 87.30 | 89.30 | 68.30 |
| Contour Canal | 127.70 | 121.30 | 113.00 | 63.30 |
| Significance (F test) | *** | ** | *** | ns |
| $LSD_{.05}$ | 17.03 | 20.09 | 14.22 | 25.86 |
| CV % | 8.71 | 10.95 | 7.73 | 19.85 |

¶/ 1st = First rainy season, 24 March - 15 July, 1993; 2nd = Second rainy season, 25 August - 15 December, 1993; 3rd = First rainy season, 9 March - 7 July, 1994; 4th = Second rainy season, 26 August 94 - 3 January, 1995;

†/ Hedgerows of *L. leucocephala*, ‡/ Rows of *P. maximum*

ns, *, **, *** = Not significant, significant at the 5 %, 1 % and 0.5 % levels of probability, respectively.

**Table A3. Percent fertile and lodged plants at harvest in first four cropping seasons. Agroforestry Adaptive Trial III.**

| Treatments | Fertile Plants/Seasons[¶] 1st | 2nd | 3rd | 4th |
|---|---|---|---|---|
| | % | | | |
| Hedgerow[†] and Fertilizer | 90.19 | 93.95 | 96.25 | 82.72 |
| Hedgerow and Grass | 83.82 | 90.10 | 85.48 | 86.44 |
| Hedgerow alone | 83.11 | 81.23 | 79.91 | 84.47 |
| Stone wall | 91.27 | 87.78 | 81.60 | 74.68 |
| Control (No Structure) | 94.59 | 87.97 | 83.63 | 72.15 |
| Grass[‡] row | 88.87 | 81.72 | 85.05 | 75.90 |
| Contour Canal | 91.93 | 92.21 | 85.38 | 73.23 |
| Significance (F test) | * | ns | * | * |
| $LSD_{.05}$ | 6.38 | 10.95 | 7.94 | 8.98 |
| CV % | 4.02 | 7.01 | 5.23 | 6.43 |
| | % Lodged Plants | | | |
| Hedgerow[†] and Fertilizer | 9.05 | 2.63 | 3.17 | 2.73 |
| Hedgerow and Grass | 6.04 | 3.23 | 4.38 | 10.13 |
| Hedgerow alone | 7.16 | 7.29 | 6.49 | 5.96 |
| Stone wall | 5.70 | 3.95 | 7.00 | 8.55 |
| Control (No Structure) | 6.40 | 2.96 | 4.12 | 7.65 |
| Grass[‡] row | 5.89 | 3.28 | 5.91 | 9.16 |
| Contour Canal | 5.78 | 3.66 | 6.61 | 11.24 |
| Significance (F test) | ns | ns | ns | * |
| $LSD_{.05}$ | 6.55 | 3.51 | 4.22 | 4.66 |
| CV % | 56.05 | 51.14 | 44.10 | 33.08 |

¶/ 1st = First rainy season, 24 March - 15 July, 1993; 2nd = Second rainy season, 25 August - 15 December, 1993; 3rd = First rainy season, 9 March - 7 July, 1994; 4th = Second rainy season, 26 August 94 - 3 January, 1995;

†/ Hedgerows of *L. leucocephala*, ‡/ Rows of *P. maximum*

ns, * = Not significant and significant at the 5 % level of probability, respectively.

by the control and grass row treatments.

Percent grain moisture during the first and third cropping season (first rainy season or Season A) was generally lower than that in the respective second and fourth cropping seasons (second rainy season or Season B).

## Maize Stand Counts

Stand counts differed significantly ($P < 0.005$) during the first three cropping seasons. In the first three seasons, as expected, the control, contour canal and stone wall treatments gave significantly higher stands with no differences among them (Table A5). Stand loss was greatest with hedgerows alone during the first three seasons.

In the fourth cropping season, maize germination was not satisfactory and damage by rodents to maize seedlings was observed. This resulted in only fair maize stands in all plots. However, stand loss was greater in plots without alley cropping (ten rows of maize), probably due to a decline in soil fertility resulting from continuous cultivation.

## Time Trends

Except for lodging and percent moisture, the trend appears to be a decline over time in control plots and treatments with soil conservation practices that do not include *Leucaena*. In alley plots with *Leucaena*, there was a slight decrease in plant stands in the fourth season whereas for other variables, parameters have tended to remain stable or to increase slightly.

Table A5. Maize stand count[§] in first four cropping seasons. Agroforestry Adaptive Trial III.

| Treatments | Count 1 / Seasons[¶] 1st | 2nd | 3rd | 4th |
|---|---|---|---|---|
| | # | | | |
| Hedgerow[†] and Fertilizer | 151.33 | 148.00 | 150.67 | 132.67 |
| Hedgerow and Grass | 154.70 | 146.00 | 151.00 | 132.33 |
| Hedgerow alone | 149.33 | 142.33 | 149.33 | 124.67 |
| Stone wall | 187.70 | 182.70 | 186.33 | 130.00 |
| Control (No Structure) | 191.00 | 179.33 | 189.33 | 132.67 |
| Grass[‡] row | 152.33 | 145.33 | 153.33 | 115.67 |
| Contour Canal | 190.30 | 182.00 | 187.33 | 128.67 |
| Significance (F test) | *** | *** | *** | ns |
| $LSD_{.05}$ | 4.06 | 10.12 | 8.26 | 29.74 |
| CV % | 1.36 | 3.54 | 2.78 | 13.05 |
| | Count 2 | | | |
| Hedgerow[†] and Fertilizer | 142.00 | 142.00 | 142.00 | 127.67 |
| Hedgerow and Grass | 146.70 | 140.33 | 135.00 | 125.67 |
| Hedgerow alone | 140.00 | 137.33 | 129.00 | 115.00 |
| Stone wall | 178.00 | 174.00 | 171.00 | 118.67 |
| Control (No Structure) | 176.33 | 175.00 | 170.00 | 122.00 |
| Grass[‡] row | 145.00 | 142.00 | 134.67 | 111.67 |
| Contour Canal | 181.33 | 175.00 | 168.67 | 113.67 |
| Significance (F test) | *** | *** | *** | ns |
| $LSD_{.05}$ | 7.67 | 9.78 | 20.14 | 32.10 |
| CV % | 2.72 | 3.54 | 7.54 | 15.14 |

¶/ 1st = First rainy season, 24 March - 15 July, 1993; 2nd = Second rainy season, 25 August - 15 December, 1993; 3rd = First rainy season, 9 March - 7 July, 1994; 4th = Second rainy season, 26 August 94 - 3 January, 1995;

†/ Hedgerows of *L. leucocephala*, ‡/ Rows of *P. maximum*

§/ Count 1 = Count after thinning, Count 2 = Count at harvest;

ns, *** = Not significant, significant at the 0.5 % level of probability, respectively.

# APPENDIX III

## SUPPLEMENTARY DATA ON HEDGEROW BIOMASS

**Table A6. Total fresh weight biomass harvested from hedgerows in first four cropping seasons. Agroforestry Adaptive Trial III.**

| Treatments | Cropping Seasons[¶] 1st | 2nd | 3rd | 4th |
|---|---|---|---|---|
| *(Leucaena and Grass)* | t/ha | | | |
| Hedgerow[†] and Grass | 40.68 | 13.61 | 12.09 | 9.26 |
| Hedgerow alone | 32.62 | 10.92 | 9.93 | 6.91 |
| Hedgerow and Fertilizer | 33.13 | 11.46 | 11.05 | 7.23 |
| Grass[‡] row | 5.73 | 4.96 | 3.37 | 2.14 |
| Significance (F test) | *** | *** | *** | *** |
| $LSD_{.05}$ | 11.42 | 3.20 | 2.84 | 2.34 |
| CV % | 20.38 | 15.66 | 15.62 | 18.38 |
| *(Leucaena biomass)* | | | | |
| Hedgerow[†] and Grass | 39.37 | 12.82 | 11.61 | 8.21 |
| Hedgerow alone | 32.62 | 10.92 | 9.93 | 6.91 |
| Hedgerow and Fertilizer | 33.13 | 11.46 | 11.05 | 7.23 |
| Significance (F test) | ns | * | ns | ns |
| $LSD_{.05}$ | 10.10 | 1.23 | 1.61 | 2.14 |
| CV % | 12.71 | 4.63 | 6.54 | 12.67 |

¶/ 1st = First rainy season, 24 March - 15 July, 1993; 2nd = Second rainy season, 25 August - 15 December, 1993; 3rd = First rainy season, 9 March - 7 July, 1994; 4th = Second rainy season, 26 August 94 - 3 January, 1995;

†/ Hedgerows of *L. leucocephala*, ‡/ Rows of *P. maximum*

ns, *, *** = Not significant, significant at the 5 % and 0.5 % levels of probability, respectively.

Table A7. Leaf fresh weight biomass harvested from hedgerows in first four cropping seasons. Agroforestry Adaptive Trial III.

| Treatments | 1st | 2nd | 3rd | 4th |
|---|---|---|---|---|
| | Cropping Seasons[¶] | | | |
| *(Leucaena and Grass)* | t/ha | | | |
| Hedgerow[†] and Grass | 10.99 | 7.98 | 7.14 | 6.56 |
| Hedgerow alone | 9.59 | 6.10 | 5.76 | 4.68 |
| Hedgerow and Fertilizer | 9.22 | 6.73 | 6.42 | 5.02 |
| Grass[‡] row | 5.73 | 4.96 | 3.37 | 2.14 |
| Significance (F test) | ns | ns | * | ** |
| $LSD_{.05}$ | 4.58 | 2.65 | 2.14 | 1.84 |
| CV % | 25.79 | 20.60 | 18.90 | 20.05 |
| *(Leucaena biomass)* | | | | |
| Hedgerow[†] and Grass | 9.67 | 7.18 | 6.66 | 5.51 |
| Hedgerow alone | 9.59 | 6.10 | 5.76 | 4.68 |
| Hedgerow and Fertilizer | 9.22 | 6.73 | 6.42 | 5.02 |
| Significance (F test) | ns | ns | ns | ns |
| $LSD_{.05}$ | 2.01 | 1.22 | 1.12 | 1.56 |
| CV % | 9.34 | 8.08 | 7.86 | 13.58 |
| *(Grass leaves)* | | | | |
| Hedgerow[†] and Grass | 1.31 | 0.80 | 0.48 | 1.05 |
| Grass[‡] row | 5.73 | 4.96 | 3.37 | 2.14 |
| Significance (F test) | ns | ns | ns | ns |
| $LSD_{.05}$ | 9.21 | 5.02 | 3.37 | 2.54 |
| CV % | 74.49 | 49.68 | 49.73 | 45.38 |

¶/ 1st = First rainy season, 24 March - 15 July, 1993; 2nd = Second rainy season, 25 August - 15 December, 1993; 3rd = First rainy season, 9 March - 7 July, 1994; 4th = Second rainy season, 26 August 94 - 3 January, 1995;

†/ Hedgerows of *L. leucocephala*, ‡/ Rows of *P. maximum*

ns, *, ** = Not significant, significant at the 5 % and 1 % levels of probability, respectively.

Table A8. Branch and stem fresh weight biomass (t/ha) harvested from hedgerows in first four cropping seasons. Agroforestry Adaptive Trial III.

| Treatments | Branches[§] /Seasons[¶] 1st | 2nd | 3rd | 4th |
|---|---|---|---|---|
| | t/ha | | | |
| Hedgerow[†] and Grass | 7.41 | 4.30 | 3.14 | 2.26 |
| Hedgerow alone | 5.94 | 3.83 | 2.88 | 1.92 |
| Hedgerow and Fertilizer | 5.90 | 3.75 | 3.06 | 1.92 |
| Significance (F test) | ns | ** | ns | ns |
| $LSD_{.05}$ | 2.03 | 0.25 | 0.29 | 0.51 |
| CV % | 13.94 | 2.83 | 4.17 | 11.04 |
| | Stems[††] / Seasons | | | |
| Hedgerow and Grass | 21.02 | 1.33 | 1.75 | 0.44 |
| Hedgerow alone | 16.60 | 0.99 | 1.29 | 0.32 |
| Hedgerow and Fertilizer | 17.59 | 0.99 | 1.56 | 0.29 |
| Significance (F test) | ns | ** | ns | ns |
| $LSD_{.05}$ | 6.80 | 0.18 | 0.68 | 0.22 |
| CV % | 16.29 | 7.28 | 19.44 | 27.86 |

¶/ 1st = First rainy season, 24 March - 15 July, 1993; 2nd = Second rainy season, 25 August - 15 December, 1993; 3rd = First rainy season, 9 March - 7 July, 1994; 4th = Second rainy season, 26 August 94 - 3 January, 1995;

†/ Hedgerows of *L. leucocephala*, §/ Branches = Green Stems < 1 cm (diameter) ††/ Stems 1-5 cm (diameter)

ns, ** = Not significant, significant at the 1 % level of probability, respectively.

Table A9. **Wood and pod biomass production in the first cropping season. Agroforestry Adaptive Trial III.**

| Treatments | Fresh Weight | | Dry Weight | |
|---|---|---|---|---|
| | Wood[†] | Pod | Wood | Pod |
| | t/ha | | | |
| Hedgerow[‡] and Grass | 0.82 | 0.44 | 0.50 | 0.27 |
| Hedgerow alone | 0.09 | 0.40 | 0.06 | 0.14 |
| Hedgerow and Fertilizer | 0.14 | 0.28 | 0.09 | 0.15 |
| Significance (F test) | ns | ns | ns | ns |
| $LSD_{.05}$ | 1.24 | 0.41 | 0.76 | 0.22 |
| CV % | 155.34 | 48.23 | 156.47 | 52.67 |

†/ Wood = Stem > 5 cm (diameter); ‡/ Hedgerows of *L. leucocephala*; ns = Not significant

Table A10. Total, leaf and branch biomass production (t/ha) in the first and second cropping seasons. Agroforestry Adaptive Trial III.

| Treatments | 1st Pruning, at planting | | | | 2nd Pruning, at 35 DAP[†] | | | |
|---|---|---|---|---|---|---|---|---|
| | Total | Leaf | Branch[‡] | Grass | Total | Leaf | Branch | Grass |
| *First Cropping Season* | | | | | | | | |
| | | | | Fresh Weight Biomass | | | | |
| Hedgerow[¶] and Grass | 33.48 | 5.60 | 5.02 | 0.57 | 7.20 | 4.07 | 2.39 | 0.74 |
| Hedgerow alone | 25.90 | 5.45 | 3.36 | | 6.72 | 4.14 | 2.58 | |
| Hedgerow and Fertilizer | 26.46 | 5.07 | 3.39 | | 6.66 | 4.15 | 2.51 | |
| Grass[$] row | | | | 3.66 | | | | 2.07 |
| | | | | Dry Weight Biomass | | | | |
| Hedgerow[¶] and Grass | 19.00 | 2.31 | 2.77 | 0.24 | 2.02 | 1.09 | 0.77 | 0.17 |
| Hedgerow alone | 13.94 | 2.10 | 1.71 | | 2.06 | 1.18 | 0.88 | |
| Hedgerow and Fertilizer | 14.37 | 2.04 | 1.78 | | 1.97 | 1.15 | 0.82 | |
| Grass[$] row | | | | 1.54 | | | | 0.49 |
| *Second Cropping Season* | | | | | | | | |
| | | | | Fresh Weight Biomass | | | | |
| Hedgerow[¶] and Grass | 6.10 | 3.04 | 1.97 | 0.02 | 6.71 | 4.14 | 2.34 | 0.78 |
| Hedgerow alone | 5.51 | 2.68 | 1.97 | | 5.42 | 3.42 | 1.86 | |
| Hedgerow and Fertilizer | 5.73 | 3.06 | 1.83 | | 5.73 | 3.67 | 1.92 | |
| Grass[$] row | | | | 2.25 | | | | 2.71 |
| | | | | Dry Weight Biomass | | | | |
| Hedgerow[¶] and Grass | 2.41 | 1.06 | 0.82 | 0.01 | 1.96 | 1.13 | 0.75 | 0.16 |
| Hedgerow alone | 2.25 | 0.95 | 0.88 | | 1.58 | 0.94 | 0.60 | |
| Hedgerow and Fertilizer | 2.38 | 1.06 | 0.82 | | 1.68 | 0.99 | 0.66 | |
| Grass[$] row | | | | 0.79 | | | | 0.62 |

[†]/ DAP = Days after planting; [‡]/ Branches = Green stems < 1 cm (diameter)
[¶]/ Hedgerows of *L. leucocephala*; [$]/ Rows of *P. maximum*

Table A11. Total, leaf and branch biomass production (t/ha) in the third and fourth cropping seasons. Agroforestry Adaptive Trial III.

| Treatments | 1st Pruning, at planting | | | | 2nd Pruning, at 30 DAP[†] | | | | 3rd Pruning, at 60 DAP | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total | Leaf | Branch[‡] | Grass | Total | Leaf | Branch | Grass | Total | Leaf | Branch | Grass |
| ***Third Cropping Season*** | | | | | | | | | | | | |
| **Fresh Weight Biomass** | | | | | | | | | | | | |
| Hedgerow[¶] and Grass | 7.92 | 3.70 | 2.27 | 0.14 | 2.45 | 1.75 | 0.71 | .[††] | 1.72 | 1.21 | 0.16 | 0.34 |
| Hedgerow alone | 6.16 | 2.86 | 2.01 | | 2.37 | 1.66 | 0.71 | | 1.39 | 1.24 | 0.16 | |
| Hedgerow and Fertilizer | 7.02 | 3.36 | 2.08 | | 2.78 | 1.96 | 0.82 | | 1.26 | 1.10 | 0.15 | |
| Grass[§] row | | | | 1.44 | | | | 1.03 | | | | 0.91 |
| **Dry Weight Biomass** | | | | | | | | | | | | |
| Hedgerow[¶] and Grass | 2.96 | 1.30 | 0.78 | 0.04 | 0.71 | 0.50 | 0.21 | . | 0.42 | 0.29 | 0.04 | 0.09 |
| Hedgerow alone | 2.27 | 0.95 | 0.71 | | 0.74 | 0.53 | 0.21 | | 0.38 | 0.34 | 0.04 | |
| Hedgerow and Fertilizer | 2.76 | 1.19 | 0.83 | | 0.77 | 0.54 | 0.23 | | 0.30 | 0.27 | 0.03 | |
| Grass[§] row | | | | 0.43 | | | | 0.29 | | | | 0.22 |
| ***Fourth Cropping Season*** | | | | | | | | | | | | |
| **Fresh Weight Biomass** | | | | | | | | | | | | |
| Hedgerow[¶] and Grass | 4.80 | 2.56 | 1.50 | 0.31 | 1.89 | 1.47 | 0.42 | . | 2.57 | 1.49 | 0.34 | 0.74 |
| Hedgerow alone | 3.76 | 2.12 | 1.32 | | 1.57 | 1.26 | 0.31 | | 1.58 | 1.29 | 0.29 | |
| Hedgerow and Fertilizer | 3.79 | 2.23 | 1.28 | | 1.48 | 1.20 | 0.28 | | 1.95 | 1.59 | 0.37 | |
| Grass[§] row | | | | 0.66 | | | | . | | | | 1.49 |
| **Dry Weight Biomass** | | | | | | | | | | | | |
| Hedgerow[¶] and Grass | 1.78 | 0.90 | 0.58 | 0.10 | 0.58 | [illegible] | 0.13 | . | 0.63 | 0.39 | 0.09 | 0.15 |
| Hedgerow alone | 1.53 | 0.81 | 0.58 | | 0.48 | 0.39 | 0.05 | | 0.41 | 0.34 | 0.07 | |
| Hedgerow and Fertilizer | 1.49 | 0.80 | 0.56 | | 0.49 | 0.41 | 0.08 | | 0.50 | 0.42 | 0.09 | |
| Grass[§] row | | | | 0.24 | | | | . | | | | 0.38 |

[†] DAP = Days after planting; [‡] Branches = Green stems < 1 cm (diameter)
[¶] Hedgerows of *L. leucocephala*; [§] Rows of *P. maximum*; [††] "." = Not harvested

# HAITI PRODUCTIVE LAND USE SYSTEMS PROJECT

**South-East Consortium for International Development**
**and**
**Auburn University**

**SECID/Auburn PLUS Reports**

**September 1996**

**Report No.**

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3. Monitoring and Evaluation System for PLUS by Angelos Pagoulatos, April 1993

4. Rapport sur les recherches d'opportunites de commercialisation pour les produits agricoles dans les aires d'intervention du Projet PLUS. by Henry Jude Belizaire and John Dale (Zach) Lea, October 1993. (Revised March 1994).

5. Guide to the Literature and Organizations Involved in Agribusiness Research and Agribusiness Development in Haiti. by Henry Jude Belizaire and John Dale (Zach) Lea, August 1993

6. Evaluation of Tree Species Adaptation for Alley Cropping in Four Environments in Haiti. A. Establishment Phase. by Dennis A. Shannon and Lionel Isaac, November 1993

7. Farmer Needs Assessment Exploratory Surveys Executive Summary Recommendations. by Richard A. Swanson, William Gustave, Yves Jean and Roosevelt St Dic, October 1993.
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9. Farmer Needs Assessment Exploratory Surveys PADF Cap Haitien Region 3 by Richard A. Swanson, William Gustave, Yves Jean, George Conde, October 1993

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