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PRELIMINARY RESULTS OF ON-STATION GREEN MANURE TRIALS WITH LEAVES FROM LEUCAENA LEUCOCEPHALA CASSIA SIAMEA AND TERMINALIA BROWNII

RESEARCH REPORT NO. 1

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REPORT OUTLINE

		PAGE
	Acknowledgements	(iii)
	List of Tables	(ii)
	List of Figures	(i)
	Annexes	(i)
1.	Introduction	1
2.	Description of the Experiment	1
3.	Observetions and results	2
3.1.	General	2
3.2.	Observations third cropping period	3
3.2.1.	Calendar of activities	3
3.2.2.	Coloration - Visual observation	3
3.2.3.	Diseases	3
3.3.	Parameters measured during the third cropping period	3
3.3.1.	Maize	3
3.3.2.	Beans	4
3.4.	Statistical treatment of data	4
3.5.	Maize treatment results	4
3.5.1.	Weed growth	5
3.5.2.	Height growth	6
3.5.3.	Leaf area index	8
3.5.4.	Weight of grains	10
3.5.5.	Grain size	11
3.6.	Bean plot results	11

a

3.6.1. Weed growth

3.6.2. Number of leaves 12

3.6.3. Number of flowers 12

3.6.4. Number of pods 14

3.6.5. Dry weight of bean seeds per plot 14

4. Interpretation of results 15

4.1. Maize treatment 15

4.2. Bean treatment 15

16

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LIST OF FIGURES

		PAGE
Figure 1 :	Mean maize height in centimetres per treatment	7
Figure 2 :	Leaf area index values for three consecutive measurements	9

ANNEXES

Annex 1 :	Beans mulch/green organic manure trial	17
Annex 2 :	Maize mulch/green manure trial	18
Annex 3 :	Rainfall data 1984/85	19
Annex 4 :	Calendar of activities	20
Annex 5 :	Formula used for testing difference between 2 treatments within the overall experiments	21

LIST OF TABLES

		PAGE
Table 1 :	Maize treatments results - F-ratios	5
Table 2 :	Weed growth maize treatments	6
Table 3 :	Height measurement comparisons	8
Table 4 :	Comparison of differences in leaf area index	10
Table 5 :	Analysis Grain weight	10
Table 6 :	Average weight of 100 grains of maize	11
Table 7 :	F-ratios individual treatment	11
Table 8 :	Weed growth bean treatments	12
Table 9 :	Analysis of bean leaves	13
Table 10:	Analysis of number of flowers	14
Table 11:	Number of pods per plant at harvest time	15
Table 12:	Average weight of bean seeds per plant	15

1. INTRODUCTION

The Dryland Agroforestry Research Project sited in Machakos District aims at developing Agroforestry technologies for the semi-arid areas of Kenya and other East African countries with a view to improving the quality of life of the inhabitants. The following are the main research objectives:-

- To examine the possibilities for maintaining/increasing the productivity of the cropping system by establishing an alley cropping system.
- To examine the possibilities for improving the quality, quantity and seasonal distribution of forage on the farm by planting fodder trees/shrub species in the grazing areas and by developing cut-and-carry forage systems;
- To examine the possibilities for reducing the labour input requirements of the free-grazing system and fuelwood collection by establishing living fences around the grazing land, and on-farm fuelwood tree planting.
- To examine the possibilities for increasing the cash income of the farmers by the introduction of fruit trees.

This research report deals with the first research objective, i.e. to maintain/increase the productivity of the cropping system by establishing an alley-cropping system in the cropland.

In this land use system, lopping of hedges at 15-30 cm above ground would take place before land preparation. The branches would be spread in the alleys between the hedges and the woody components would be removed just before ploughing and be used as fuelwood. The remaining already decomposing leaves and small twigs would be ploughed into the soil thus improving the soil nutrient status, maintaining soil organic matter and controlling erosion.

By establishing the hedges along the contour, it is also hoped that soil erosion will be reduced.

As part of the experimentation on this system, a small trial was initiated to screen the effect of different tree leaves and rates of application on plant growth once incorporated into the soil.

2. DESCRIPTION OF THE EXPERIMENT

To screen as many species and rates as possible with the limited amount of land available, it was decided to adopt a design with very small plot sizes, exposing relative differences between treatments rather than absolute differences. For this reason

yield figures cannot be extrapolated to a per hectare basis.

Two independent, completely randomised designs were used, one to test the effect of different treatments on beans, the other on maize.

The experiment was laid out between 13th and 19th October 1983 at Katumani National Dryland Farming Station, Maruba Farm. The layout is shown in Annexes 1 and 2. The following treatments were replicated four times:

- *Cassia siamea* : 1 and 2 kg/m² (wet weight)
- *Leucaena leucocephala* : 1 and 2 kg/m²
- *Terminalia brownii* : 1 and 2 kg/m²
- Control, no leafy material applied.

The leafy material was applied about 2 weeks before planting and incorporated into the soil immediately to avoid being blown off by the wind. To minimise the influence of slope, small ridges were made around each plot.

For the test crops the following spacings were adopted:-

Beans: (Phaseolus sp) Each plot had one row of 10 beans plants, 15 cm between plants.
Maize: (Zea mays) Each plot had one row of 6 maize plants, 30 cm between plants.

To observe the effect of continued green manuring on the same piece of land, the same experiment was repeated in March 1984 at the onset of the long rains and also in October 1984 during the short rains.

3. OBSERVATION AND RESULTS

3.1. General

The trials of the first cropping period (October 1983) were seriously damaged by the attack of birds, squirrels and dickdicks. During the second cropping period, the experimental area was fenced with chicken wire mesh. It was observed that whereas the dickdicks were excluded by the chicken wire mesh, the squirrels burrowed underneath the wire while the birds continued from above. The squirrels operated between 6.00 and 8.00 a.m. and 3.00 - 5.00 p.m. A watchman had to be deployed during these periods each day. The second cropping period (March 1984) was also unsuccessful due to rain failure. It was decided to make use of Katumani's overhead irrigation system to avoid such problems in the future.

The third cropping period (October 1984) was finally successful, all previously mentioned bottlenecks having been removed. No overhead irrigation was required since the rains were satisfactory (see Annex 3). The results reported are from this third crop

ping period trials.

3.2. Visual Observations

3.2.1. Calendar of Activities.

The calendar of activities for the third cropping period is summarised in Annex 4.

3.2.2. Coloration - Visual Observation

Between three to four weeks after germination, both maize and beans showed marked differences in degree of greenness depending on the kind of treatment.

Maize plants in the *Cassia siamea* and *Leucaena leucocephala* plots appeared dark green - the greenness being more marked in plants under 2 kg/m².

Plants in the plots under *Terminalia brownii* green manure were yellowish green at both levels.

The differences in coloration ceased after two months for all treatments.

The observed coloration differences in beans was as described for maize above. The beans assumed a green coloration slightly over one month after germination.

3.2.3. Diseases

No fungal disease was observed in maize plots.

Armyworms infested both types of plots late in November and stalk borers infested maize repeatedly.

Triodam 35% EC at 60 mls per 20 litres of water and Dedevap 50% EC at about 2 ml per litre of water were sprayed repeatedly to control the armyworms and stalk borers.

3.3. Parameters measured

3.3.1. Maize

Height : from ground level (base to tip of the longest leaf (third leaf from the top); for first and second height measurements.

Overall height : from ground level to tip of tassel; for third measurement.

Length of third leaf : from base to tip of leaf.

Width of third leaf: - breadth of the broad lower part of the leaf.

breadth of the narrow upper part of the leaf.

Number of cobs per plant.

Weight of cobs per plant (air dry).

Weight of grains per plant (air dry).

Grain weight : weight (in grams) per 100 grains (oven-dry).

3.3.2. Beans

Number of leaves per plant.

Number of flowers per plant.

Number of pods per plant.

Weight of seeds per plant (oven dry).

3.4. Statistical treatment of data.

The analyses were conducted with the help of ABSTAT, a commercially available micro computer software package. Before entering the data into the computer all individual plant observations were screened for failures and near failures.

Next, the results from each treatment, (distributed over 4 plots) were examined with a view to increasing the sensitivity of the analysis by using individual plant observations instead of average plant observation per plot.

Next, a one way analysis of variance was used to test whether differences between treatments were statistically significant.

Once differences between all treatments were found to be significant at a 1 or 5% level, further analysis was conducted to test for differences between the control and a treatment as well as between treatment levels 1 and 2 for each type of leafy material (see Annex 5).

3.5. Maize treatment results

A total of 168 plants distributed over 7 treatments and 4 replications was observed.

An analysis of the variance for 'between' and 'within' plot variations for each treatment for one of the measured parameters (dry weight of harvested cobs) gave the following F-ratios.

Table 1 : F-ratios

Treatment	F-ratios (df 5,18)
Cassia 1	1.5
Cassia 2	2.1
Leucaena 1	0.83
Leucaena 2	3.07
Terminalia 1	0.85
Terminalia 2	1.51
Control	0.17
Overall	1.43

From these F-ratios it was noted that the within- and between-plot variances for each treatment were was not significant and hence individual observations rather than the mean parameters per plot used for further analysis, thus increasing the degrees of freedom for error.

3.5.1. Weed growth

The following weeds were common in each maize and bean plot.

Cynodon dactlon
Oxygonum sinuatum
Digitaria scalarum
Commelina africana
Sonchus schweinfurthii
Bidens pilosa
Solanum nigrum
Ocimum basilicum
Tagetes minuta
Amaranthus spp
Gynandropsis gynandra
Asystasia schimperi
Cyperus spp

The dry weight of weeds expressed in grams of dry weight per plot (i.e. 1.62 m²) at the time of first weeding (6 weeks after planting) was averaged for each treatment and summarised in Table 2.

Table 2 · Weed growth in maize plots.*

Treatment	av.weight	Standard deviation
Cassia 1	57.1	45.1
Cassia 2	51.9	3.8
Leucaena 1	54.5	35.6
Leucaena 2	84.5	47.5
Terminalia 1	36.7	15.7
Terminalia 2	35.6	16.3
Control	33.2	15.7

*in grams of dry weight/plot of 1.6 m^2

Although there were indications that weed growth in the Terminalia 1 and 2 and the control plots were lower than average, while weed growth in the Leucaena 2 plots are higher, the differences between treatments were not significant in a statistical sense (F-value is 1.42). The probable cause for this difference in weed growth is the quick release of nutrients from Leucaena. This seems to be confirmed by the observation on coloration.

3.5.2. Height growth

The height of the plants was recorded 1, 2 and 3 months after germination. The results are summarised in Figure 1.

The analysis of variance for the three sets of measurements gave the following F-values: 8, 6 and 2.7 respectively. (Significant at 1, and 5% respectively; degrees of freedom 6, 161).

A comparison of height between individual treatments and control and between levels of application gave the following results (see also Table 3).

- At the time of first measurement, Cassia siamea 2 and Leucaena leucocephala 2 were about 21% taller than the control (F-values: 9.21 and 9.82 respectively which are significant at 1% level). The probable cause is the quick release of nutrient as compared to the others.

- Terminalia brownii at 2 kg/m^2 had a significantly lower mean than the control at 1% level.

- Cassia 2 and Leucaena 2 were significantly better than Cassia 1 and Leucaena 1, while the reverse was true for Terminalia.

- The second measurement showed the same trend as for the first set with the exception of Terminalia 1 which performed much better. A slower decomposition of the Terminalia

leaves seems to result in a retarded efffect on plant growth.

- At the final measurement, the three 'best' treatments (Terminalia 1, Cassia 2 and Leucaena 2) yielded an a 18% higher plant height.

- Terminalia 2 throughout the growing period gave much lower results than Terminalia 1 and did not result in any improvement as compared to the control. No explanation could be found for this behaviour.

Fig. 1 : Mean maize height

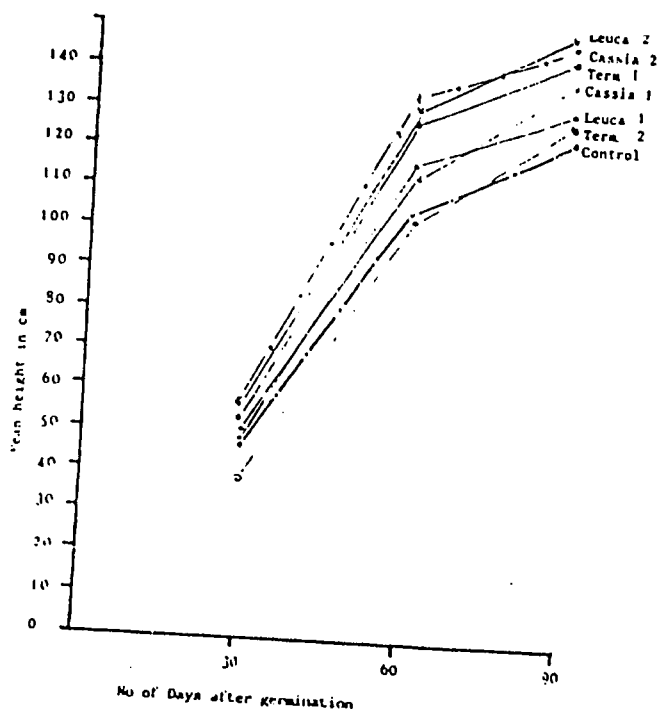


Table 3 : Height Comparisons

Treatments	%Difference first value	F-ratio (df 1,16)
after 1-month		
Control vs Terminalia 2	-18.0	6.77***
Control vs Leucaena 1	2.0	0.08
Control vs Cassia 1	6.8	0.94
Control vs Terminalia 1	13.4	3.60
Control vs Cassia 2	21.4	9.21***
Control vs Leucaena 2	22.1	9.82***
Cassia 1 vs Cassia 2	13.7	4.27*
Leucaena 1 vs Leucaena 2	19.6	8.09***
Terminalia 1 vs Terminalia 2	-28.0	20.25***
after 2-month		
Control vs Terminalia 2	-1.6	0.05
Control vs Cassia 1	8.7	1.65
Control vs Leucaena 1	10.7	2.52
Control vs Terminalia 1	21.2	9.89***
Control vs Leucaena 2	24.8	13.55***
Control vs Cassia 2	27.4	16.48***
Cassia 1 vs Cassia 2	17.2	7.69***
Leucaena 1 vs Leucaena 2	12.8	4.38*
Terminalia 1 vs Terminalia 2	-18.8	11.42***
after 3-month		
Control vs Terminalia 2	3.5	0.26
Control vs Leucaena 1	5.3	0.59
Control vs Cassia 1	11.0	2.52
Control vs Terminalia 1	15.9	5.4***
Control vs Cassia 2	18.5	7.29***
Control vs Leucaena 2	20.8	9.23***
Cassia 1 vs Cassia 2	6.9	1.23
Leucaena 1 vs Leucaena 2	15.4	5.15*
Terminalia 1 vs Terminalia 2	-10.7	3.27

*** - significant at 1% level
* - significant at 5% level

3.5.3. Leaf area index

The leaf area index was determined at the same time plant heights were measured.

First of all the leaf area (LA) was determined using the following formula (length of third leaf (cm) x average width of third leaf (cm) x 0.75).

The leaf area index was then calculated as follows:-

$$\frac{\text{LA} \times \text{number of leaves}}{\text{area occupied by one plant (90 x 30 cm)}}$$

The resulting leaf area indices are summarised in Fig. 2.

The analysis of variances showed that differences between treatments were significant at the first two measurement. F-value respectively 6, 3.83) but not for the last measurement (F-value = 2.81).

It should be noted that the leaf area index was highest at the second month after germination.

A comparison between individual treatments and the control and between levels of applications for the first two measurements gave the following results. (see Table 4).

- Terminalia 1, Leucaena 2 and Cassia 2 had a very significant impact on the leaf area index (70-80% increase).
- Terminalia 2 gave significantly lower leaf area index than Terminalia 1 (F-ratio 8.90).

Fig. 2 : Leaf area index values for three consecutive measurements

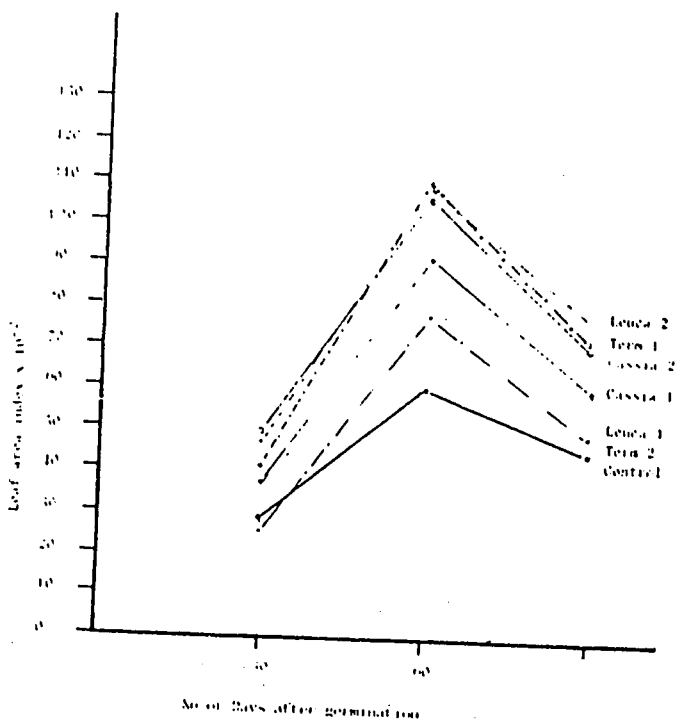


Table 4 : Comparison of differences in leaf area index.

Treatment	%Difference first value	F-ratio (df1,16
after 1-month		
Control vs Terminalia 2	-11	0.33
Control vs Cassia 1	35	3.61
Control vs Leucaena 1	35	3.61
Control vs Terminalia 1	44	5.68*
Control vs Leucaena 2	66	12.85***
Control vs Cassia 2	76	17.13***
Cassia 1 vs Cassia 2	30	4.96*
Leucaena 1 vs Leucaena 2	23	2.82
Terminalia 1 vs Terminalia 2	-38	8.94***
after 2-month		
Control vs Terminalia 2	28	1.62
Control vs Leucaena 1	33	2.31
Control vs Cassia 1	51	5.58*
Control vs Cassia 2	69	10.23***
Control vs Leucaena 2	79	13.26***
Control vs Terminalia 1	80	13.71***
Cassia 1 vs Cassia 2	12	0.69
Leucaena 1 vs Leucaena 2	35	4.48*
Terminalia 1 vs Terminalia 2	-29	5.89*

*** at 1% level
* at 5% level

3.5.4. Grain Weight per plant

The analysis of the grain weight are summarised in Table 5.

Table 5 : Analysis Grain Weights

Treatment	Av.weight(gr)	Rank	%Difference with control	%Difference between apl.level	F-ratio (df 1,161) control	F-ratio (df 1,161) apl.level
Cassia 1	51.2	1	-12.3	-	0.59	-
Cassia 2	74.2	5	27.0	14.5	1.98	4.36*
Leucaena 1	71.2	4	21.7	-	1.29	-
Leucaena 2	92.2	6	57.8	12.9	9.03***	3.48*
Terminalia 1	92.2	6	57.8	-	9.04***	-
Terminalia 2	60.1	3	2.9	-34.8	0.02	8.15**
Control	58.4	2	-	-	-	-

*** significant at 1%
* significant at 5%

The differences between treatments was found to be signifi-

cant at 1% level (F-ratio = 4.15).

Terminalia 1 and Leucaena 2 were by far the best treatments, increasing the per plant grain weight (dry) by almost 60%.

There was a statistically significant difference between levels of applications for both Cassia and Leucaena, however such difference were small (13-15%).

Terminalia 2 was again lower than Terminalia 1.

3.5.5. Grain Size

The average weight of 100 grains was taken as a measure of grain size. There was no statistical significance between the treatment (F-ratios 0.76). Table 6 gives the average weight of 100 grains per plant per treatment in grams.

Table 6 : Average Weight of 100 Grains of Maize

Treatment	Mean (grams)	Standard deviation
Cassia 1	33.8	10.7
Cassia 2	32.6	12.5
Leucaena 1	34.4	10.3
Leucaena 2	40.7	39.8
Terminalia 1	35.3	7.5
Terminalia 2	35.1	13.7
Control	29.7	14.6

3.6. Bean plot results

A total of 280 plants, distributed over 7 treatments and 4 replications, was observed.

An analysis of the variance for 'between' and 'within' plot variations for each treatment for one of the main parameter (weight of harvested beans seeds) gave the following F-ratios:-

Table 7 : F-ratios individual treatment

Treatment	F-ratios (df 9.30)
Cassia 1	1.96
Cassia 2	5.04
Leucaena 1	6.77
Leucaena 2	3.92
Terminalia 1	2.52
Terminalia 2	3.24
Control	0.55
Overall	3.42

Based on these F-ratios it was decided that between and within plot variance for each treatment differed significantly and hence mean plot values rather than individual observations were used for further analysis.

3.6.1. Weed growth

The weed growth expressed in grammes of dry weight per plot i.e. 0.9 m^2 measured at the time of the first weeding and the results are summarised in Table 8. (see 3.5.1. for the composition of weeds).

Table 8 : **Weed growth beanplot treatment***

Treatment	Av.weight	Standard deviation
Cassia 1	15.7	1.5
Cassia 2	20.8	9.2
Leucaena 1	18.9	7.7
Leucaena 2	21.0	6.0
Terminalia 1	22.8	19.0
Terminalia 2	15.2	5.8
Control	29.7	13.0

* in grams of dry weight/plot

Unlike the maize plot results, there is no clear pattern emerging. Also the differences between treatments were not significant (F-value 0.89).

3.6.2. Number of Leaves

Leaf counts were made in November and December; the results are summarised in Table 9.

The differences between treatments were statistically significant for both counts (F-ratios respectively 14.87 and 5.81).

A comparison between treatments and the control and between levels of application gave the following results.

- Leucaena 2 and Terminalia 1 gave a 25-26% increases over the control (F-ratios respectively 9.7 and 10.4).
- Cassia 1 and 2 at the first count were well below the control.

Table 9 : Analysis of Bean Leaves

Treatment	Av. number of leaves		Rank		%difference Control		%difference apl. level		F-ratio with contr		F-ratio below levels	
	1	2	1	2	1	2	1	2	1	2	1	2
Cassia 1	5.5	7.8	1	1	-21	-8	-	-	21.3***	0.96	-	-
Cassia 2	5.9	9.1	2	4	-16	7	7	17	11.8***	0.73	1.36	3.43
Leucaena 1	7.3	8.0	4	2	4	6	-	-	1.02	0.43	-	-
Leucaena 2	7.8	10.6	7	6	11	25	7	33	5.5*	9.7***	1.75	14.24***
Terminalia 1	7.7	10.7	6	7	10	26	-	-	4.74*	10.4***	-	-
Terminalia 2	7.3	9.5	4	5	4	12	-5	-11	0.61	2.37	1.91	2.54
Control	7.0	8.5	3	3	-	-	-	-	-	-	-	-

*** significant at 1% level

* significant at 5% level

13

- Terminalia 2 gave lower results than Terminalia 1 at both counts although these differences were statistically not significant.

- Leucaena 2 gave 33% better results than Leucaena 1 at the second count (F-ratio 14.24).

3.6.3. Number of flowers

The summary of the average number of flowers per plant after 80 days from planting are recorded in Table 10.

The differences between treatments were significant at 1% level (F-ratio 6.3).

A comparison between the different levels and between levels of application gave the following results:

- With the exception of Leucaena 1 and Terminalia 2, all treatments gave a significantly lower number of flowers at the time of counting. Since the number of pods and bean seeds later on were not significantly lower, it seems to indicate that flowering is retarded by the use of green manure.

- Leucaena 2 gave a significant lower flower count (23%) which seems to confirm the previous observation.

Table 10 : Analysis of number of flowers

Treatment	Av No.	Rank	%difference		F-ratio (df 1,21)	
			with control	between apl.level	control	apl.level
Cassia 1	3.9	1	-37	-	7.29*	-
Cassia 2	4.0	2	-35	3	6.53*	0.02
Leucaena 1	8.4	7	35	-	6.53*	-
Leucaena 2	5.7	3	-9	-23	3.78	10.20***
Terminalia 1	5.8	4	-7	-	0.03	-
Terminalia 2	6.2	5	0	-8	0	0.03
Control	6.2	5	-	-	-	-

*** significant at 1% level
* significant at 5% level.

3.6.4. Number of pods per plant at harvesting time

Although there were differences between number of pods at harvesting time, these differences were statistically not significant (F 1.03). The results are summarised in Table 11.

Table 11 : Number of Pods per Plant at Harvest Time

Treatment	Mean	Standard deviation
Cassia 1	4.4	0.54
Cassia 2	4.2	0.78
Leucaena 1	4.3	0.69
Leucaena 2	4.5	0.64
Terminalia 1	5.2	0.67
Terminalia 2	3.8	1.87
Control	3.8	0.70

3.6.5. Dry weight of bean seeds per plant

Although all treatments gave better results than the control, varying from 11 to 30%, an analysis of variance of all treatments gave an F-value of only 0.38, meaning that differences were not significant and may have been caused by chance. The results are summarised in Table 12.

Table 12 : Average weight of bean seeds per plant

Treatment	Av Weight (in grams)	Standard deviation
Cassia 1	7.4	1.58
Cassia 2	7.3	3.28
Leucaena 1	8.5	3.44
Leucaena 2	8.0	2.22
Terminalia 1	8.6	2.15
Terminalia 2	6.4	2.15
Control	6.6	0.87

It may also be noted that for all species the 1 kg/m² application gave better results than the 2 kg application.

4. INTERPRETATION OF RESULTS

4.1. Maize treatments

Leucaena 2, Terminalia 1 and Cassia 2 gave the best results for height growth, leaf area index and grain weight. The Terminalia 2 treatment showed some sort of an inhibitory effect on all these growth parameters, which cannot be explained at the moment.

Preliminary results from trials elsewhere in Machakos District gave a green matter yield for Leucaena of about 1.5 kg per tree per season at an average in-row spacing of 0.62 m and a between row spacing of 3.5 meters. Per hectare production of leafy material per season is therefore approximately 6,900 kg to be distributed over a crop area of 6,600 m² (1/3 of the total area being occupied by the hedges), reaching an application of about 1

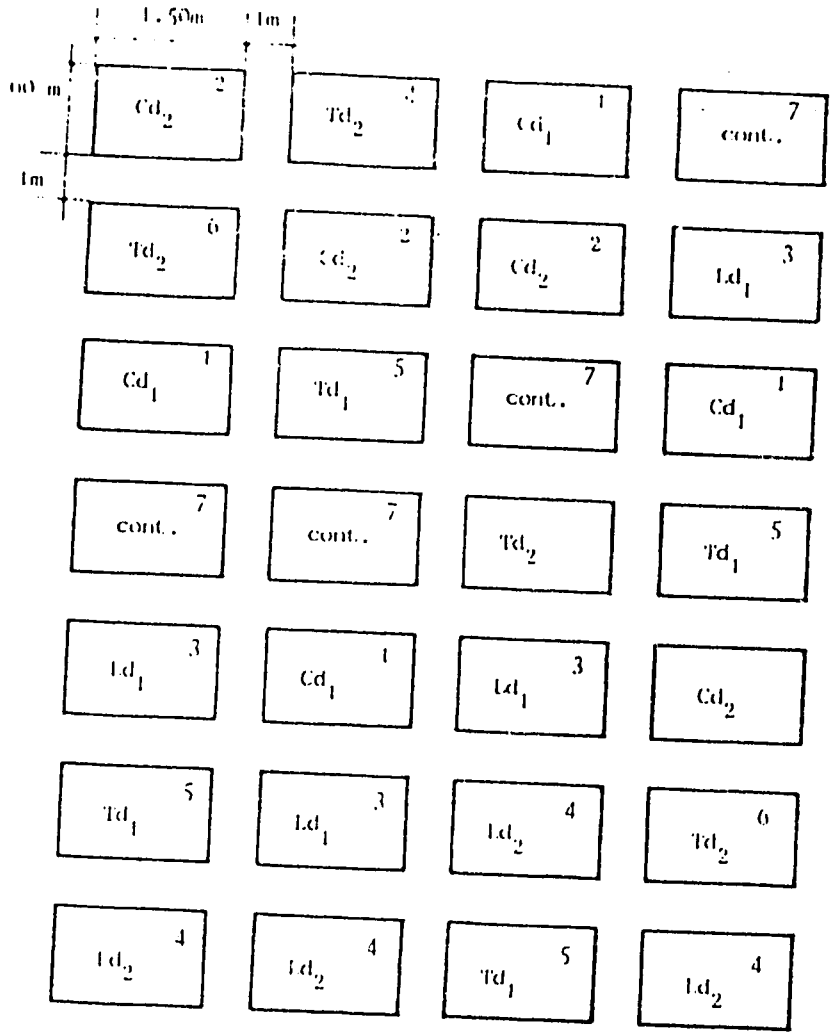
kg/m². At this rate the relative yield of maize per unit of crop area would only increase by 22% in case of Leucaena, which would be insufficient to off-set the reduction in yield due to land loss (33%). No biomass figures are available for Terminalia, however if it is assumed to be the same as Leucaena (which is doubtful), the overall maize production per hectare would increase by 6% (58% over 67% of the area).

Although these preliminary results are not all that promising, some further study into the system seems justified because long term effects on soil fertility, interaction between the hedgerows and the crops as well as biomass production potential from the hedgerows are still largely unknown under semi arid conditions.

4.2. Bean treatments

The effect of the different treatments on the bean growth appear to be less dramatic than for maize. Also, the results are statistically not very conclusive with the exception of the leafy growth.

BEANS MULCH/GREEN ORGANIC MANURE TREAT

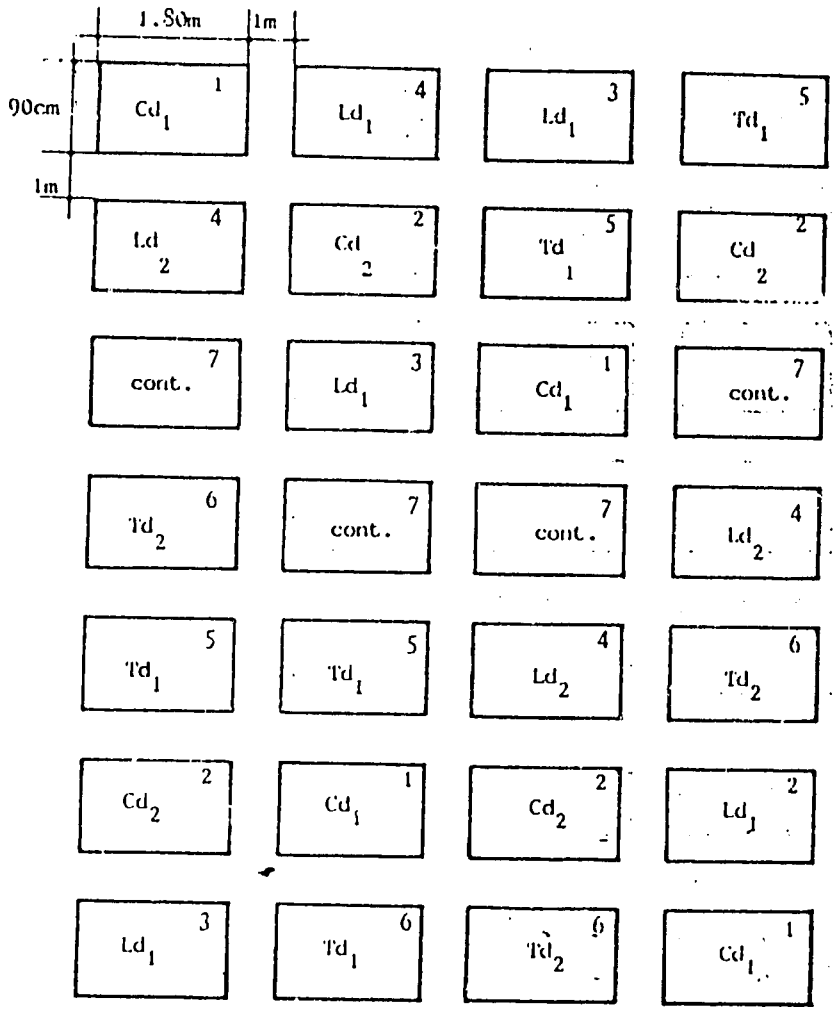


Treatment Combinations

1. Ld_1 - Leucaena leucocephala @ 1 kg/m².
2. Ld_2 - Leucaena leucocephala @ 2 kg/m².
3. Cd_1 - Cassia siamea @ 1 kg/m².
4. Cd_2 - Cassia siamea @ 2 kg/m².
5. Td_1 - Terminalia brownii @ 1 kg/m².
6. Td_2 - Terminalia brownii @ 1 kg/m².
7. C - Control

Total amount of mulch required/10.80 kg of each! (Fresh weight). Each plot will have 1 row of beans spaced 15 cm apart (10 plants).

MAIZE MULCH/GREEN MANURE TRIAL

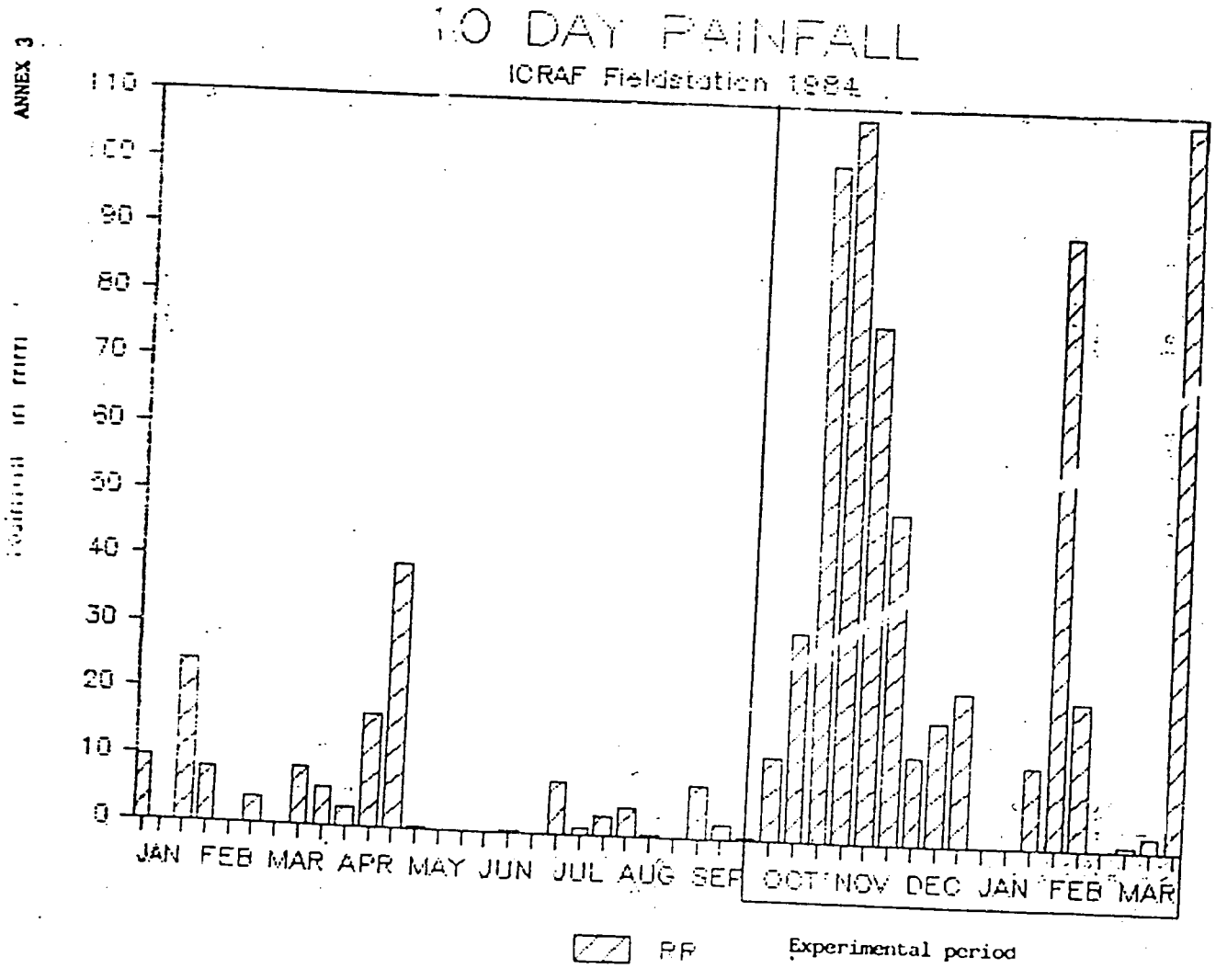


Treatment Combinations

1. Cd_1 - Cassia siamea @ 1 kg/m².
2. Cd_2 - Cassia siamea @ 2 kg/m².
3. Ld_1 - Leucaena leucocephala @ 1 kg/m².
4. Ld_2 - Leucaena leucocephala @ 2 kg/m².
5. Td_1 - Terminalia brownii @ 1 kg/m².
6. Td_2 - Terminalia brownii @ 2 kg/m².
7. Cont.___ control (maize only, no mulch applied!)

Total amount of mulch required Leucaena) 19.44 kg of each
Cassia) fresh weight
Terminalia)

ANNEX 3


10 DAY RAINFALL
ICRAF Fieldstation 1984
Rainfall in mm
110
100
90
80
70
60
50
40
30
20
10
0
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR
RR
Experimental period

ANNEX 4

Calendar of Activities

Maize

Agricultural activities	Dates
- Mulching	15/10/84
- Planting	16-17/10/84
- Weeding	29/11/84
- Harvesting	6/3/85

Monitoring	
- Record of Germination	22-23/10/84
- Leaf count and leaf measurements	23/11/84; 23/12/84; 23/1/85
- Weighing of wet cobs	6/3/85
- Dry weight record of cobs	3/4/85
- Weighing 100 grains	5/4/85
- Weighing dry grains	6/4/85
- Soil sampling: for soil moistures*	12/11/84; 12/12/84
for rate of decomposition*	12/1/85; 12/2/85

Beans

Agricultural activities	
- Mulching	15/10/84
- Planting	17/10/84
- Weeding	29/11/84
- Harvesting	23/1/85

Monitoring	
- Leaf count	23/11/84; 23/12/84
- Flower count	23/11/84
- Pod count	23/12/84
- Length of dry pods	23/12/84
- Bean seed count/plant	6/2/85
- Weighing of beans/plant	12/2/85
- Soil sampling: for moisture*	12/11/84; 12/12/84;
for rate of decomposition*	12/1/85; 12/2/85

*not yet analysed

ANNEX 5

Formula used for testing differences between 2 treatments within the overall experiment.

$$\frac{\left[\frac{(n_1 \times m_1)^2}{n_1} + \frac{(n_2 \times m_2)^2}{n_2}\right] - \left[\frac{((n_1 \times m_1) + (n_2 \times m_2))^2}{n_1 + n_2}\right]}{\text{residual mean sq all treatments}}$$