Agroforestry Systems **13**: 1–11, 1991.

Shading effects of alley cropped *Leucaena leucocephala* on weed biomass and maize yield at Mtwapa, Coast Province, Kenya

BASHIR JAMA[1], AMARE GETAHUN[2] and D.N. NGUGI[2]
[1]*Current address: School of Forest Resources and Conservation, Department of Forestry, University of Florida, Gainesville, FL, 32611, USA*
[2]*International Council for Research in Agroforestry (ICRAF), P.O. Box 30677, Nairobi, Kenya*

Key words: Leucaena, alley cropping, shade, fallow period, weed biomass, maize yield, coastal Kenya

Abstract. Reductions of up to 90% in weed biomass was observed under *Leucaena leucocephala* alley cropping with varying tree between (2, 4 and 8 m) and within-row spacing combinations when compared to crop-only control. An increase of 24 to 76% in maize yields of alley cropped plots compared to the crop-only control was also recorded. The 2 m alley widths closed canopy faster than the 4 and 8 m, and hence realized highest weed biomass reduction during the short-fallow period between two cropping seasons. At the end of the short fallow period, substantial fuelwood (up to $8\,t\,ha^{-1}$) was realized.

Introduction

Crop yields along the coastal strip of Kenya are low. Regional average for maize, the staple food crop falls below one ton per hectare (Muturi 1981). Among other factors such as low fertility, pests and diseases, weeds are estimated to account for up to 40–50% of field losses (Michieka 1981). Weed control takes over 50% of the total time needed to produce a crop (Anon. 1984). Use of fallow periods to control weeds and regenerate soil fertility after cropping for 2 to 3 seasons is a common practice in the region. Fallow periods are however now of a shorter duration and probably ineffective due to increasing human population pressure for arable land.

Agroecosytems built on principles of fallow periods' soil fertility restoration and weed control that could increase acreage and length of cropping would be desirable in such areas. One such system is alley cropping multipurpose trees and shrubs (MPTS) as described in Kang et al. (1981). Studies on weed control aspects of alley cropping MPTS are however few. Budelman (1988) and Yamoah et al. (1986) investigations emphasized the importance of litter quality and rate of decomposition in weed control. In species like leucaena with rapid rates of litter decomposition, weed control aspects of litter may be negligible and shade effects may be more important. From long-term leucaena alley cropping trials at Mtwapa, Çoast Province, Kenya, this paper reports two related aspects: a) declines in biomass and species of weeds and b) improvements in yield of maize for two years, 1985 and 1986.

Experimental site

The study was conducted at Mtwapa Agroforestry/Energy Center, located at 15 m above mean sea level, latitude 3° 50′S and longitude 39° 45′E, Coast Province, Kenya. The mean annual rainfall is approximately 1300 mm and is bimodally distributed ('long-rains', April–June; 'short-rains', October–December). Annual evapotranspiration rates approximate 2000 mm while temperatures range from 21 to 32 °C. The soil, inherently low in nutrients is classified as Inceptisol-oxic tropepts (USDA classification system) or Ferralic Cambisols (FAO).

Materials and methods

Leucaena leucocephala (var. K28) seedlings were established in May 1982 in a parallel systematic-row spacing (Bleasdale 1967) design. Treatments were made of three tree row spacings (2, 4 and 8 m) and 4 within-row spacings (0.5, 1, 2, and 3 m) combinations, each with five internal replications. Five replicates of crop-only control plots were also established adjacent to the alley cropped plots (Figure 1). Parallel-row systematic spacing design, in spite of its statistical inadequacies (Huxley 1985) was used because with minimal commitment of scarce experimental resources, it does facilitate combined demonstration and preliminary investigations of tree/crop intercropping at different planting densities (Huxley 1987), thus fulfilling two principal objectives of the studies.

Tree side pruning to single stems and to 0.5 m hedges above-ground were carried out two-and-half and three years respectively after planting to reduce shade and provide green leaf manure (GLM) to the intercrop. Woody prunings were removed from the fields.

Maize (Coast composite var.) and green gram (*Phaseolus aureus*) were sown in the 'long' and 'short' rains seasons respectively in alleys formed by leucaena hedgerows. Before and during each cropping season, 1 × 1 m square quadrants were randomly located in each plot; weed species present

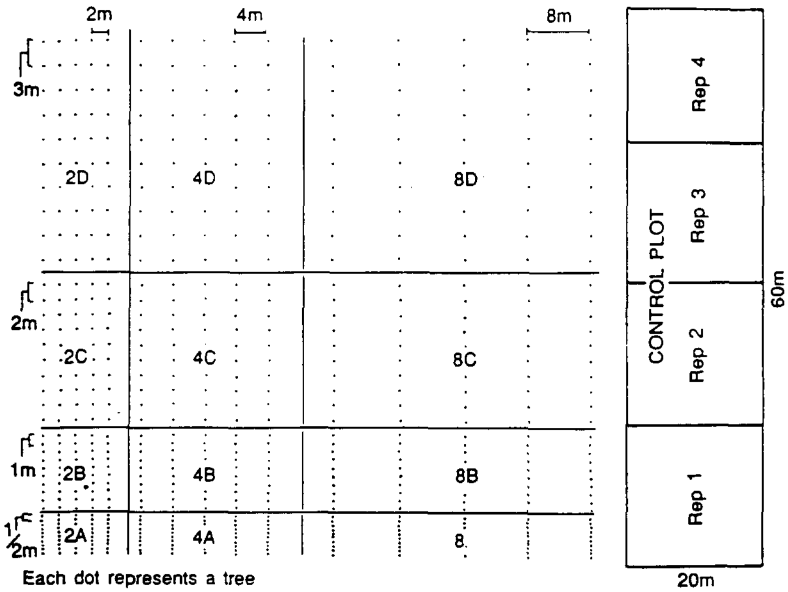

Fig. 1. Field layout of alley cropped *Leucaena leucocephala* and the adjacent crop-only plots.

were identified and their cumulative weights determined. At crop harvest, grain yields of each treatment were recorded. Activity calendar of tree/crop management for the study period reported (May 1982 to September 1986) is presented in Table 1.

Data gathered were subjected to analysis of variance (ANOVA). This form of analysis was felt justifiable given the physical uniformity of the site and the absence of significant differences in initial soil chemical characteristics (Table 2) between the plots. Where differences between treatments were significant, means were separated by Duncan's Multiple Range Test at $p = 0.05$. It is recognized that site variability may be underestimated by design used and ANOVA (Mead and Stern 1979). The outcome of treatments may therefore, until a randomized design is used, be treated as indicative rather than conclusive.

Results

Weed biomass under leucaena at end of the prolonged establishment phase (March, 1985) were, relative to control plot's yields, reduced significantly by leucaena row spacing (Figure 2). Within-row spacing effects on weed biomass were not significant. These reductions range from 64 to 98% for 8

Table 1. Activity calendar of tree/crop management under *Leucaena leucocephala* alley cropping

	Activity	Year				
		1982	1983	1984	1985	1986
1.	Tree planting	May				
2.	Maize planting	May				
3.	Green gram planting		October			
4.	Maize planting			April		
5.	Tree side pruning			September		
6.	Green gram planting			October		
7.	Green gram harvest[1]					
7.	First tree pruning to 0.5 m above-ground				March	
8.	Second tree pruning to 0.5 m above-ground				May	
9.	Third tree pruning to 0.5 m above-ground				September	
10.	Green gram planting				October	
11.	Green gram harvest[2]					
12.	Fourth tree pruning to 0.5 m above-ground					March
13.	Maize planting					April
14.	Fifth tree pruning to 0.5 m above-ground					May
15.	Sixth tree pruning to 0.5 m above-ground					Sept.
16.	Green gram planting					Oct.

[1] No harvest due to shade from (side pruned) trees.
[2] No harvest due to crop failure from drought (due to poor rainfall distribution).

and 2 m leucaena between-row spacings respectively. The various species of weeds present after tree establishment period (or at start of first pruning back to 0.5 m above-ground as shown in Table 1), categorized into either grasses or non-grasses (Table 3) indicate significant control of many species, particularly under 2 m wide alleys.

Table 2. Initial chemical properties of top soil (0–15 cm depth) of experimental plots, May 1983

Row spacing (m)	pH	%			ppm.
		K	Ca	organic C	P
2	6.1	0.2	2.0	0.3	24.0
4	5.9	0.1	1.6	0.3	22.0
8	6.1	0.1	2.4	0.4	37.0
control	6.0	0.1	2.5	0.4	32.0

Weed biomass after a period of active alley cropping (i.e., frequent pruning back of the hedges) shown in Table 4 were reduced significantly by row spacing of leucaena hedgerows in this order: 2 m < 4 m < 8 m. Also numbers of weed species (not presented here) were on average twice as many in the control than in the alley cropped plots. Within-row spacing effects of

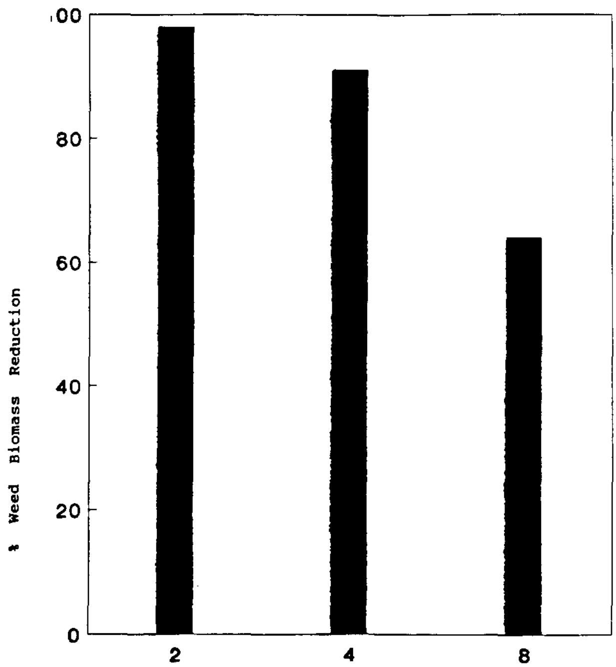

Fig. 2. Percent reduction in weed biomass under alley cropping relative to the control plots.

Table 3. Weed species present in intercropped leucaena alleys/hedgerow spacings (m) and the control plot in January 1985

Weed species		Present/Absent in alleys			Control
		2	4	8	
	Grass species/sedges				
1.	*Eleusine indica*	x	x	x	x
2.	*Cynodon dactylon*	x	x	x	x
3.	*Digitaria* sp.	x	x	x	x
4.	*Imperata cylindrica*	x	x	x	x
5.	*Cyperus rotundus*	o	x	x	x
6.	*Digitaria velutina*	o	x	x	x
	Non-grasses				
7.	*Acrocarpus* sp.	x	x	x	x
8.	*Phylanthus* sp.	x	x	x	x
9.	Leucaena seedlings	x	x	x	x
10.	*Corchorus* sp.	x	x	x	x
11.	*Melhania* sp.	x	x	x	x
12.	*Ipomea* sp.	x	x	x	x
13.	*Triumfetta* sp.	o	x	x	x
14.	*Amaranthus hybridus*	o	o	x	x
15.	*Commelina benghalensis*	o	o	x	x
16.	*Commelina* sp.	o	x	x	x
17.	*Lantana camara*	o	x	x	x
18.	*Ocium basilicum*	o	x	x	x
19.	*Oxygonium sinuatum*	o	x	x	x
20.	*Flagellaria guinensis*	o	x	x	x
21.	*Dactyloctenium aegyptium*	o	x	x	x
22.	*Portulaca* sp.	o	x	x	x
23.	*Euphorbia hirta*	o	x	x	x
24.	*Acalypha volkensis*	o	x	x	x
25.	*Amaranthus* sp.	o	o	x	x
26.	*Boerhavia diffusa*	o	o	x	x
27.	*Vigna parkeri*	o	o	x	x
28.	*Vigna* sp.	o	o	x	x
29.	*Perargonium guinguelobatum*	o	o	x	x

x-present
o-absent

Table 4. Mean effect of row spacing of leucaena hedgerows on weed biomass, August 1985

Row spacing (m)	Mean yield (g/m^2, fresh weight)
2	47.5 a
4	107.5 b
8	168.0 c
Control	650.0 d

Means within a column and with the same letter do not differ significantly by DMRT at $P = 0.05$

leucaena hedgerows on weed biomass were not significant. These observations were repeatable in 1986.

Pruning back of the hedges after a short fallow period (3 months) in between 1985 'long' and 'short-rains' cropping seasons resulted in substantial yields of fuelwood, for instance 8 t/ha from the 2 m by 0.5 m tree spacing combination. At the start of the pruning activity, the trees were 3.6 m tall on average and had closed canopy in the 2 m wide alleys. GLM from this fallow period made up 50–62% of the total 28–32 t/ha/yr realized, for instance from the closest tree spacing of 2 m by 0.5 m.

Maize yields were significantly higher under leucaena alley cropping than the control plots (Table 5). This was the case even in a droughty year like 1986 with poor rainfall distribution. Maize yield was affected by significant row and within-row spacing interaction of leucaena hedgerows although definite trends could not be isolated. However, taking the average across years, yield superiority of the narrow row spacings of leucaena hedgerow spacings such as the 2 and 4 m over the 8 m and the control becomes obvious.

Table 5. Mean effect of row spacing of leucaena hedgerows on maize yield ($t\,ha^{-1}$) of 1985 and 1986 long-rains season

Year	Row spacing (m)			control	Mean
	2	4	8		
1985	3.4 a	2.8 b	2.7 bc	2.6 c	2.9
1986	2.0 a	1.3 b	0.8 c	0.5 b	1.2
Mean	2.7	2.1	1.8	1.6	

Means in a given year followed by the same letter do not differ significantly from each other by DMRT at $P = 0.05$

Discussion

Shade effects during the tree establishment phase (before first tree pruning back to 0.5 m above-ground in Table 1) accounted probably for most of the weed control effects observed. While this period could certainly be shorter than the two-and-half years of this study, it is however necessary to make it sufficiently long, not only for weed control purposes but also to develop strong stem base to support subsequent frequent prunings for GLM production during the period of active alley cropping. Crop yields were normal for about 18 months of the establishment period. Thereafter shading effects became excessive.

Of most significance outcome are the reductions in weed biomass (Table 4) achieved by the short fallow period (3 months) in between two cropping seasons. Crops were absent from fields at this time and so there were no losses to shade. Compared to the control plots, reduction in weed biomass at the end of this period was on average 93% in the alley cropped plots. These declines were attributed partially to reduced photosynthetically active radiation reaching the soil surface, an explanation consistent with observations of others (Kang et al. 1981; Yamoah et al. 1986; Hedge 1982). Leucaena grows and coppices fast to close canopy rapidly, especially in the 2 and 4 m wide alleys. The resultant shade effects rather than physical suppression effects of GLM is the most plausible explanation of the reductions in weed species and biomass. Moreover, leucaena GLM decomposes fast, about 40 days in the humid tropics (Budelman 1988) and may therefore contribute little to physically suppress weeds. Observations of Yamoah et al. (1986) of negative correlation between weed yields and tree floor litter for some alley cropped multipurpose trees and shrubs however suggest some physical suppression of weeds by GLM. Allelopathic chemicals, e.g., mimosine and/or other compounds (Kuo et al. 1982) that have been suggested to suppress initial development of maize seedlings (Akodundu 1986) could also be involved in reductions of weed species and biomass observed.

Most of the weed species in the alley cropped plots were broadleaved and easy to dislodge than the sedge grass species such as *Cyperus rotundies* that were abundant in the control plots. The absence under 2 m alleys of difficult-to-control weeds such as *Oxgonium sinuatum* which generally have longer reproductive cycles and therefore stay in the field for a longer period than many other herbaceous weeds (Ivens 1982), could mean significant savings on soil nutrients. The high maize yields (Table 5) and enhanced nutrient status (Bashir et al. 1986) under leucaena alley cropping plots may, in addition to application of leucaena GLM be explained by reduced weed incidence observed compared to the control plots. In droughty years like

1986, soil moisture conservation resulting from microclimate amelioration (Kedir et al. 1987) and better weed control could be responsible for reduced maize yield losses observed under alley cropping compared to the control.

Key to successful management of leucaena alley cropping for weed control includes minimizing risks of the species itself becoming a weed. The cultivar used (K28) seeds profusely, and potentials for weediness are likely to be high under humid conditions and where frequencies of pruning are low. Volunteer leucaena seedlings/wildings were present, more so in adjacent uncropped fields than the cropped areas. Establishment of leucaena seedlings in fields as potentially difficult-to-control weeds could however be an area of major concern in leucaena alley cropping under humid conditions. It is best to cut back the hedges before they seed. The pruning frequency of two-and-half to three months fallow period (Table 1) adopted in this study appeared to minimize seeding and therefore weediness of leucaena. At the end of this fallow period, substantial fuelwood may be realized.

Pruning back the hedges within the fallow period could also be a management option to reduce weediness but fields could be exposed to invasion by new pioneer weed species or the proliferation of others with large seed banks that are already present. Besides, costs of frequent pruning may become prohibitive under conditions of resource-poor farmers. In order to optimize weed control through canopy closure during fallow periods and at the same time minimize chances of leucaena becoming a weed, there is need to select and breed for less seedy cultivars. Other fast growing MPTS such as *Gliricidia sepium*, *Cassia siamea* and *Flemingia macrophyla*, have been reported to effectively suppress weeds under alley cropping, through the effect of their slow decomposing leaf litter (Yamoah et al. 1986; Budelman 1988). These are worth considering.

Conclusion

This study indicates remarkable reduction in weed biomass and weed types under leucaena alley cropping. Shade during fallow period in-between two cropping seasons account for probably most of the weed biomass reductions although partial involvement of physical and/or chemical effects of GLM cannot be discounted. Soil moisture and nutrients conservation resulting from good weed control measures was felt responsible for the enhanced maize yields under leucaena alley cropping with 24 to 76% increase over the control. Such improved maize yields were achieved at reduced weeding frequencies and weeding costs. From the weed control levels observed, it is feasible that direct sowing of crops may indeed be possible without or with minimal tillage of fields after the fallow period. In an area such as the coastal strip of Kenya where weeds alone may account for significant losses of crops, leucaena alley cropping could, given the good weed control and enhanced crop yields discussed above, potentially be a technology beneficial to resource-poor farmers. Leucaena can however become a weed. In the absence of less 'weedy' cultivars, frequent pruning to minimize seeding may be suggested. On pruning back the trees at the end of the short fallow period between cropping seasons, substantial fuelwood could be realized.

Acknowledgement

We are greatly indebted to the Ministry of Energy, Kenya, for permission to use the data reported here. We are also grateful to the entire field staff of Mtwapa Agroforestry/Energy Center and in particular Dickson Mwatsuma and Ester Mwaro for supervising the studies.

References

Akodundu IO (1986). Allelopathic potentials of selected legume species. Annual Report, International Institute of Tropical Agriculture. pp 15–17. pp 3

Anon. (1984). Weed control in maize experiments under coastal conditions. Coast Agricultural Research Station, Kenya

Bashir Jama, Amare Getahun, David Ngugi and Bill Macklin (1986). Leucaena alley cropping for the Kenya coast. In: Prinseley RT and Swift MJ (eds). Amelioration of soil by trees. Commonwealth Secretariat, UK pp 115–165

Bleasdale JKA (1967). Systematic designs for spacing experiments. Expl Agric 3: 73–85

Budelman A (1988). The performance of the leaf mulches of *Leucaena leucocephala, Flemingia macrophylla* and *Gliricidia sepium* in weed control. Agroforestry Systems 6: 137–145

Hedge N (1982). Leucaena foliage management in India. In: Leucaena research in Asian-Pacific Region. Proceeding of workshop held in Singapore. International Development Research Center, Canada

Huxley PA (1985). Systematic designs for field experimentation with multipurpose trees. Agroforestry Systems 3: 197–205

Huxley PA (1987). Agroforestry experimentation: separating the wood from the trees?. Agroforestry Systems 5 (3): 251–275

Kang BT, Sipkens L, Wilson GF and Nangju D (1981). *Leucaena leucocephala* (Lam) de Wit pruning as nitrogen source for maize. Fertilizer Research 2; 279–287

Kedir R, Getahun A and Jama B (1987). The influence of rain fall distribution on the yield of maize under *Leucaena leucocephala* alley cropping at Mtwapa, Coast Province, Kenya. In: Reifsnyder WS and Darnhofer TO (eds). The application of meteorology to agroforestry systems planning and management. ICRAF (International Council of Research in Agroforestry), Nairobi. pp 383–389

Kuo YL, Chou CH and Hu TW (1982). Allelopathic potential of *Leucaena leucocephala*. Leucaena Research Reports 3: 65

Ivens GW (1982). East African weeds and their control. Oxford University Press. pp 71–72

Mead R and Stern RD (1981). Statistical considerations in experiments to investigate intercropping. In: Willey RW (ed). Proceedings of the international workshop on intercropping. ICRISAT (International Crops Research Institute for the Semi-arid Tropics), Patancheru, India. pp 263–276

Michieka RW (1981). Weed research survey in Kenya. A report for the National Council for Science and Technology, Kenya pp 8

Muturi SN (ed) (1981). Agricultural research at the coast. Report No. 6 of the National Council for Science and Technology, Kenya pp 6

Yamoah CF, Agboola AA and Mulongoy K (1986). Decomposition, nitrogen release and weed control by prunings of selected alley cropping shrubs Agroforestry Systems 4: 239–246