EFFECT OF *LEUCAENA LEUCOCEPHALA* (LAM.) DE WIT PRUNING FREQUENCY ON ALLEY CROPPED MAIZE/CASSAVA

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Key words: cassava, hedgerow, *Leucaena leucocephala*, light intensity, maize, pruning frequency

Abstract: *A study was undertaken to assess the effect of different pruning intervals of Leucaena leucocephala hedgerows on alley cropped maize and cassava. Farmers often delay hedgerow pruning in alley cropping systems due to labor and financial constraints. It is not clear, however, when hedgerow shading becomes detrimental to crop growth. Crop growth and yield were measured in relation to available light and soil moisture under Leucaena hedgerows which were pruned every 2, 4, 6, 8 and 10 weeks. A control of unpruned hedgerows was included. Marked reductions in maize yield were recorded when hedgerow pruning was delayed beyond 10 weeks after crop planting; while cassava yield was not affected. A general trend of taller plants with thinner stems was observed when Leucaena hedgerows were not pruned or pruned at intervals of 8 weeks. Plants adjacent to hedgerows were usually shorter than those in the middle of the alleys. Yield decline and growth effects were attributed to shading, rather than soil moisture depletion by the hedgerows. This study demonstrated that hedgerow pruning can be delayed up to 10 weeks after planting maize without significant yield reduction. Further studies are necessary to determine optimum pruning intervals for a maize/cassava intercrop in an alley cropping system.*

1. Introduction

Agroforestry systems are inherently complex. By definition, crops are grown in close association with trees or shrubs in these systems. Consequently, resource pools are shared by both components and the potential for competition exists between them. This is an important issue since the system aims to produce large amounts of tree biomass for mulch, fodder or fuelwood while simultaneously sustaining crop production [Kang et al. 1989]. Since minimizing negative interactions while optimizing crop and tree productivity is a major goal, tree management is an important tool in controlling competition for resources between food crops and tree species [Buck 1986, Rosecrance et al. 1992]

The negative effects of excessive hegerow biomass production on crop productivity have been amply demonstrated. In alley cropping systems, Ong et al. (1990) observed lower overall crop yields in alley cropped plots, and particularly depressed yields of plants grown in rows adjacent to infrequently pruned *Leucaena* hedgerows compared to control (no tree) plots. In another study, yield reductions were also associated with increasing hedgerow biomass [Rosecrance et al. 1992]. Field and OeMatan (1990) also found a significant decline of grain yield of maize alley cropped with *Leucaena* that was pruned less than once a season.

Alley cropping studies in the sub-humid tropics suggest that hedgerow shading can severely limit crop productivity; however, research in the semi-arid regions shows that competition for water between crop and tree, takes precedence over light [Singh et al. 1989]. Competition for nutrients can also be a concern in alley cropping systems on inherently infertile soils [Gichuru and Kang 1990] and/or when hedgerow prunings are exported rather than used as mulch in the field. Pruning management, however, can affect one or more aspects of tree/crop competition.

The effects of different pruning regimes of *Leucaena* hedgerows on the growth and yield of intercropped maize and cassava are discussed in this paper. How long can hedgerow pruning be delayed before light and/or soil moisture resources affect the associated crops. Are crops grown adjacent to *Leucaena* hedgerows more affected than those in the middle of the alleys?

2. Materials and Methods

2.1 Site and planting details

The study was carried out at the International Institute of Tropical Agriculture (IITA) in Ibadan, southwestern Nigeria during the 1991 and 1992 growing seasons. The mean annual rainfall is 1280 mm, which is bimodally distributed. The first rains generally begin in March and end in the beginning of August; a second rainy season begins in September and ends in October. Different experimental sites were selected for the 1991 and 1992 trials. Plot size in 1991 was 8 m x 4 m; larger plots (30 m x 4 m) were used in 1992 to facilitate pruning labor measurements. Experimental plots were arranged in a randomized complete block design with three and four replications in 1991 and 1992. The soil at both sites was an Alfisol, classified as an Oxic Paleustalf (USDA) of the Egbeda and Ibadan soil series. *Leucaena leucocephala* (Lam.) de Wit (cv K28) hedgerows were initially established in 1985 at both sites, at an interrow spacing of 4 m and an intrarow spacing of 0.25 m. In 1991, the hedgerows were pruned every 2, 4, 6, 8 and 10 weeks, after planting (WAP) maize, to a height of 30cm. Pruning intervals of 4, 6, 8 and 12 weeks (to 0.5 m height) were implemented after maize planting in 1992. The hedgerows were pruned initially on May 14-18, 1991 and April 14-15, 1992. Treatments with pruning intervals of 6 and 12 weeks were carried out in order to simulate the farmer's pruning habits, i.e., once during the maize season or only at maize harvest. An unpruned treatment was included in both years.

Prior to planting in both years, all plots were sprayed with 3.7 kg a.i/ha of paraquat for weed control. The plots were subsequently planted to maize (TZSR-W) on 31 May 1991 and 6 May 1992 at a spacing of 0.4 m x 0.8 m (31, 250 plants/ha). Cassava (TMS 30572) was planted one week later in each year at a spacing of 0.8 m x 1.6 m (7,812 plants/ha). There were four intercropped maize/cassava rows per alley. Compound fertilizer (15-15-15) was applied to supply 30 kg N/ha, 13 kg P/ha and 25 kg K/ha. One month later, maize was sidedressed with 15 kg N as CAN (calcium ammonium nitrate). The maize was harvested 31 August 1991 and 16 August 1992. The cassava was harvested 15 June 1992.

2.2 Crop growth characteristics and yield

Growth characteristics for maize and cassava were measured in both years for 4 plants adjacent to *Leucaena* hedgerows (80 cm from the trees) and in the middle of the alleys (160 cm from the hedgerows). Maize plant height and leaf area were recorded three times during the 1991 cropping season and biweekly in 1992. Biweekly maize stem diameter and leaf number measurements were also included in 1992. The percentage of maize plants that tasseled and silked was recorded at 6 weeks after planting in 1992 to determine effects of pruning interval on maize reproductive stages. Cassava height, stem diameter, internode length and leaf area were measured on a biweekly to monthly basis during the 1991 cropping season. These measurements were repeated in 1992 from May to August, at which time the experiment was terminated. Harvest plot size of 32 m^2 was used in 1991 to determine maize and cassava yields; 20.5m^2 was harvested for maize in 1992. Some cassava plants in the unpruned plots were lost during 1991 maize harvest due to the accidental application of a pesticide. Consequently, this treatment was not included in the analysis for cassava yield. Cassava plants were separated into roots, main and lateral shoots at harvest for other treatments. At maize harvest, stover and grain yields were determined in both years. All plant materials were dried at 65°C for dry matter determination.

2.3 *Leucaena* growth and pruned biomass

Leucaena plant height and pruned biomass were measured at every pruning. Whole rows (8 m long) in 1991 and 5 m sections in 1992 were harvested for dry matter determination. When stems exceeded 2 cm diameter, foliage and stem weights were recorded separately and dry matter determined.

2.4 Solar radiation

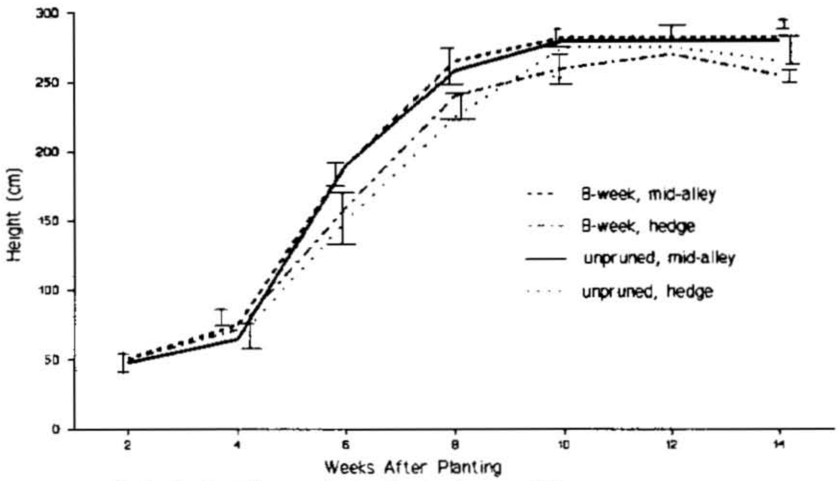
Light transmission to maize and cassava were measured in both years during the maize growing season. In 1991, a Li-Cor 1000 solarimeter tube was used to record light transmission. In 1992, a Li-Cor plant canopy analyzer was used to measure LAI which was expressed as light transmission values which were comparable to 1991 data. In 1991, light transmission was measured for all treatments; in 1992, transmission was measured for the 4-weekly pruning and no-pruning intervals. Light transmission or LAI was recorded between 11:00 A.M. and 1:00 P.M. at maize ear height, above the cassava canopy (until cassava was higher than *Leucaena* and harvested maize) and under the open sky. Light transmission was recorded adjacent to hedgerows and in the middle of the plot in 1991, but only adjacent to hedgerows in 1992. Transmission in 1992, refers to direct radiation (i.e., only one component of radiation) versus global (or total) radiation in 1991.

2.5 Soil moisture
Soil moisture was determined gravimetrically for the 0-15 cm soil layer. Composite samples were collected adjacent to the hedgerow and in the middle of the alleys in both years. Samples were taken before and after pruning for all treatments in 1991, and in 4-, 6- and 12- weekly pruned plots in 1992. To obtain a soil moisture profile over time, samples were collected daily towards the end of the rainy season for 1991.

2.6 Data analysis
Data were analyzed either as a completely randomized block one-way or split-plot design using PROC GLM in the SAS package [SAS 1985]. When log or square root transformations did not correct non-normally distributed data or those with heterogeneous variances, rank transformations were used [Conover and Iman 1981]. Where differences between treatments were significant, means were separated using Duncan's multiple range test.

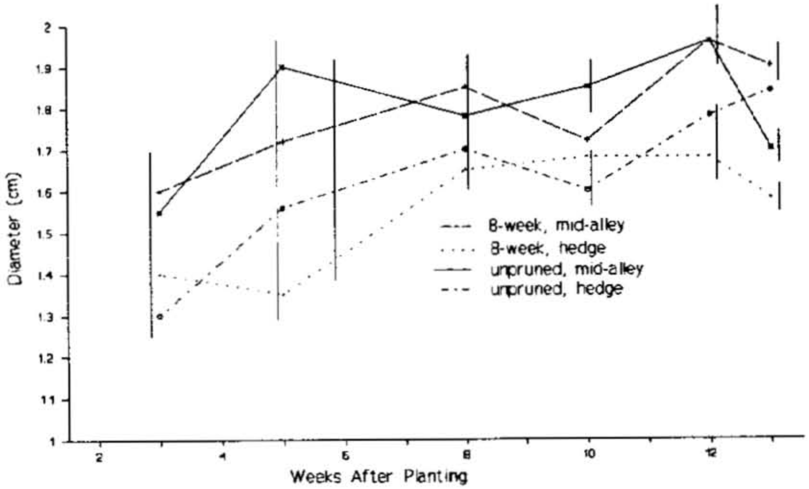
3. Results
3.1 Crop growth characteristics
Maize. Distance from *Leucaena* hedgerows had a greater effect on maize growth than pruning intervals, although fewer maize plants tassled in controls where hedgerows were not pruned during the growing season. Differences in growth were not consistent across the years of the experiment. No significant differences were observed in maize growth characteristics in 1991. In the second year of the study, however, maize plants were significantly taller with thinner stems in unpruned plots compared to pruned plots, but were not taller than maize plants where a 4-week pruning interval was done. Plant height and stem diameter differences, however, did not occur until 12 WAP. Leaf number and LAI did not differ significantly in 1992.

Proximity to hedgerows affected stem diameter and height by 5 and 6 WAP respectively. Maize plants were consistently taller with greater basal diameter in the middle of the alleys than those growing adjacent to the hedgerows in all treatments (figures 1 and 2). Plants adjacent to the hedgerows also had fewer leaves, although, leaf area index did not differ significantly with pruning interval or distance from hedgerows.



Note: Vertical lines indicate standard error of the mean

Figure 1. Maize plant height as affected by distance from *Leucaena* hedgerows in 8-week pruning intervals and unpruned plots during the 1992 maize cropping season.



Note: Vertical lines indicate standard error of the mean

Figure 2. Maize basal stem diameter as affected by distance from *Leucaena* hedgerows in 8-week pruning intervals and unpruned plots during the 1992 maize cropping season.

Significantly fewer plants tasseled and silked in the unpruned plots than in plots with 4 and 8 week pruning intervals. This phenomenon increased in maize plants growing adjacent to hedgerows when compared to plants in mid-alley in the unpruned plots and the plots with the 8-week pruning interval (data not shown).

Cassava. Cassava growth characteristics were also affected by pruning interval, but the effect of their proximity to the hedgerows was not clear. Although growth differences were fairly consistent in 1991, in 1992 there were wide disparities in cassava growth characteristics because at least 30% of the cassava cultivars were replaced at 2 weeks due to poor sprouting. In 1991, cassava node lengths were affected by pruning WAP intervals, with longer nodes under longer pruning intervals and unpruned plots, compared to shorter nodes under shorter intervals (figure 3). Cassava plants in plots that were not pruned or pruned only every 10 weeks were also significantly taller compared to those from a 2-week pruning interval (figure 4). Plants grown next to *Leucaena* were taller compared to those in the middle of alleys early in the growing season, while node length and stem diameter were not affected.

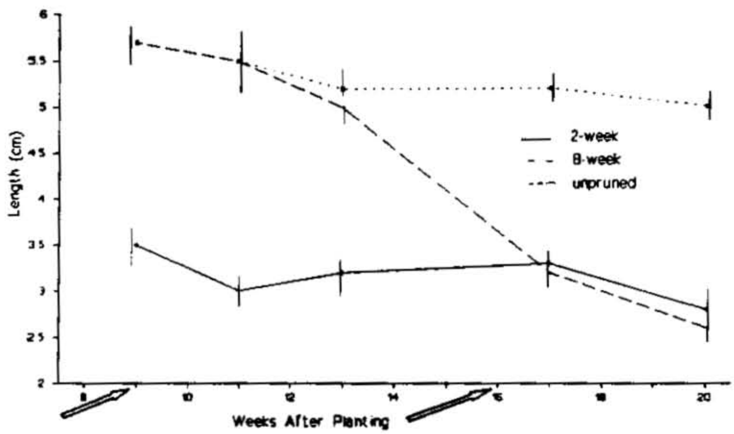
3.2 Crop yields

Maize grain and stover yields differed between years and were significantly affected by pruning intervals in both years (table 1). In plots where hedgerows were not pruned before maize harvest, maize grain yields were reduced by almost 50% compared to yields under pruned hedgerows. Generally grain yields were lower adjacent to hedgerows compared to the middle of the alleys with longer pruning intervals and in unpruned plots (table 2).

Table 1. Maize grain and stover yields (t/ha) as affected by *Leucaena* hedgerow pruning* interval

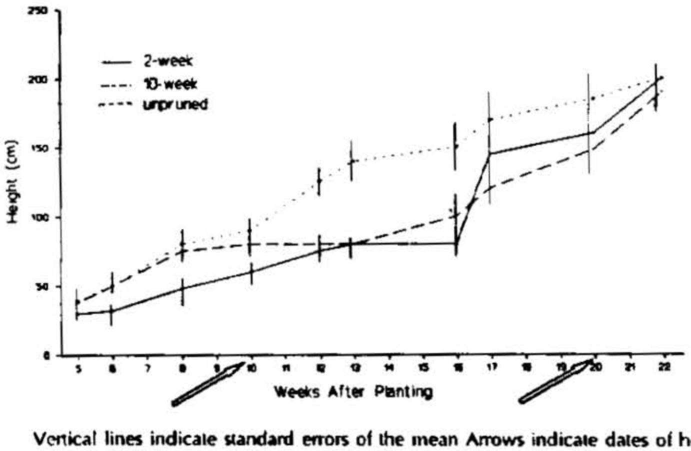
Pruning Interval	1991		1992	
(weeks)	Grain	Stover	Grain	Stover
2	3.12a	3.29a	-	-
4	3.11a	3.34a	4.33a	7.33a
6	3.12a	3.56a	4.63a	6.35a
8	3.23a	4.16a	4.70a	7.76a
10	2.71a	3.89a	-	-
12	-	-	2.04b	4.65b
unpruned	1.98	3.20	2.19b	4.57b

Note: *Hedgerows pruned to 25cm height in 1991 and to 30cm height in 1992
**Values with different letters differ within columns at the P 0.05 significance level using Duncan's multiple test.



Note: Vertical lines indicate standard errors of the mean. Arrows indicate dates of hedgerow pruning for the 8-week pruning interval

Figure 3. Cassava internode lengths for the 2 and 8 pruning intervals and in unpruned plots during the first 18 weeks of cassava growth in 1991.



Note: Vertical lines indicate standard errors of the mean Arrows indicate dates of hedgerow pruning for the 10-week pruning interval.

Figure 4. Cassava plant height for the 2-, 6- and 10- week pruning intervals and in unpruned plots during the 1991 rainy season.

Table 2. Maize grain yields (t/ha) as affected by distance from *Leucaena* hedgerow

Pruning interval (weeks)	1991		1992	
	Hedgerow	Mid-alley	Hedgerow	Mid-alley
4	2.96a	3.26a	4.35a	4.31a
6	3.26a	2.97a	4.70a	4.57a
8	3.14a	3.31a	4.57a	4.83a
10	2.08a	3.14b	-	-
12	-	-	1.72b	2.36b
unpruned	1.53b	1.50	1.95b	1.48b

Note: *values with different letters differ within rows at the P0.05 significance level using Duncan's multiple test.

Stover yields were unaffected by pruning intervals in 1991; in 1992 however, stover production was significantly lower in unpruned plots. All yield components differed significantly between pruned and unpruned treatments, the cobs were smaller and the kernels were fewer and lighter. Lower yields were also apparent in plants which were grown adjacent to the hedgerow in the 8-week pruning interval. The harvest index was not significantly lower, however, in unpruned plots compared to pruned plots in both years.

Cassava tuber yield in 1991 was not significantly affected by different pruning intervals; neither was total dry matter production (table 3). Only lateral shoot yield differed significantly among treatments. Cassava grown in plots that were pruned less frequently had higher lateral shoot yield than those grown under the more frequently pruned treatments. Distance from *Leucaena* was not a significant factor in determining cassava dry matter yields.

Table 3. Cassava dry matter yields (kg/plant) as affected by *Leucaena* hedgerow pruning intervals

Pruning interval (weeks)	Tuber yield	Lateral shoot yield	Total dry matter yield
2	0.50	0.15	1.72
4	0.69	0.15	1.97
6	0.49	0.32	1.34
8	0.30	0.29	1.79
10	0.40	0.29	1.66

3.3 Light

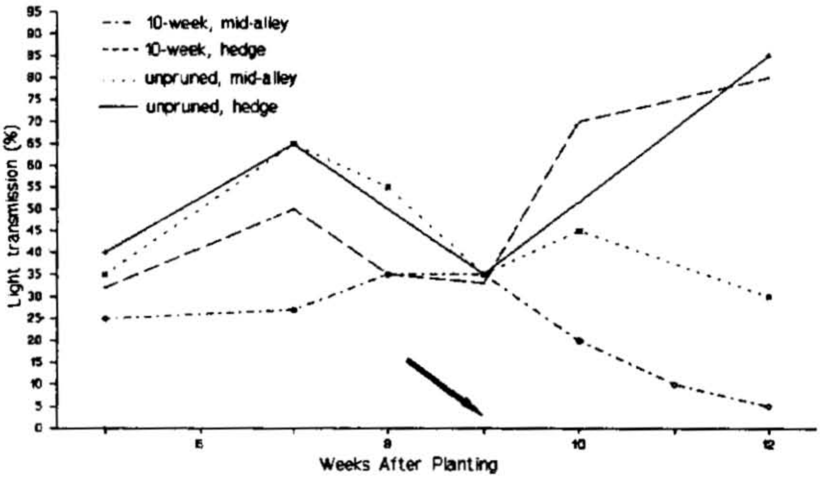
Maize and cassava were shaded by *Leucaena* hedgerows in both years and most markedly in plots where hedgerows were pruned infrequently or unpruned. Crops that were grown in plots where hedgerows were cut between 2 and 6 weeks, received on average, 60% and 30% more light than those left uncut for longer intervals. This was particularly noticeable in the first 2-3 months of growth of both crops when they were shorter relative to the *Leucaena*. Cassava received almost 50% less light than maize during this period, due to a combination of hedgerow and maize light interception.

In the unpruned maize plots, light transmission to maize gradually decreased by over 50 per cent over the growing season (figure 5). However, when *Leucaena* was pruned every 10 weeks, a different pattern emerged. Prior to pruning, light transmission to maize was higher in the middle of alleys. After pruning, however, more light was transmitted to plants adjacent to the hedgerow than in the middle of the alleys, where shading by other maize plants contributed to a reduction in light (figure 5). Data from 1992 indicates that pruning every 4 weeks did not have much affect on light transmission to maize.

Low light transmission levels were observed at the cassava canopy under 10-week pruning intervals. In the unpruned plots, low light transmission levels remained consistent throughout the period of measurement. Under a 10-week cutting interval, (figure 6) light transmission gradually decreased until pruning, after which light increased and reached 100% after maize harvest. After pruning, more light was transmitted to cassava plants adjacent to the hedgerows compared with the middle of the alleys where shading by both maize and cassava occurred. As expected, when hedgerows were pruned every 4 weeks, shading to cassava decreased after pruning (data not shown). When light transmission was related to the difference in height between *Leucaena* and crops, a significant relationship was detected (r^2 = 0.80, P = 0.0002 for maize; r^2 = 0.57, P = 0.0002 for cassava). Light transmission approached 100% as the difference between the *Leucaena*, maize and cassava heights decreased (figures 7 and 8) .

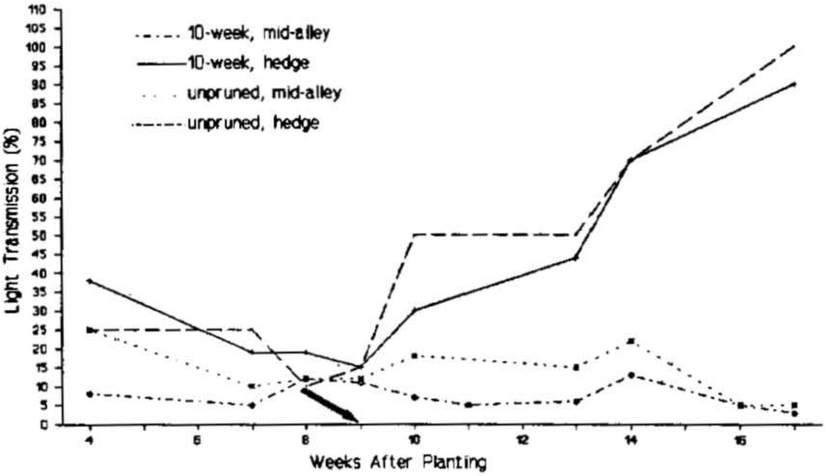
3.4 Soil Moisture

Soil moisture distribution was not significantly affected by pruning intervals or by distance from hedgerows during the 1991 and 1992 maize growing seasons. After the maize harvest and toward the end of the 1991 rainy season, however, unpruned plots were 20% drier (10% vs. 13% moisture content) than the mean value of pruned treatments.



Note: Arrow indicates date of hedgerow pruning.

Figure 5. Light transmission (%) to maize ear level in the middle of the alleys and adjacent to *Leucaena* hedgerows during the 1991 cropping season under a 10-week pruning interval and no pruning.



Note: Arrow indicates date of hedgerow pruning.

Figure 6. Light transmission (%) to cassava canopy in the middle of the alleys and adjacent to *Leucaena* hedgerows during the 1991 cropping season under a 10-week pruning interval and unpruned plots.

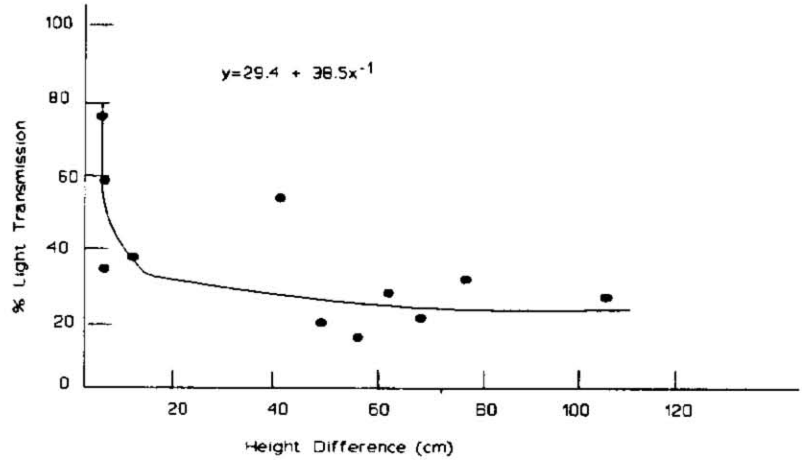


Figure 7. Relationship between % light transmission to maize ear level and the difference in height between maize and *Leucaena* during the 1991 maize cropping season

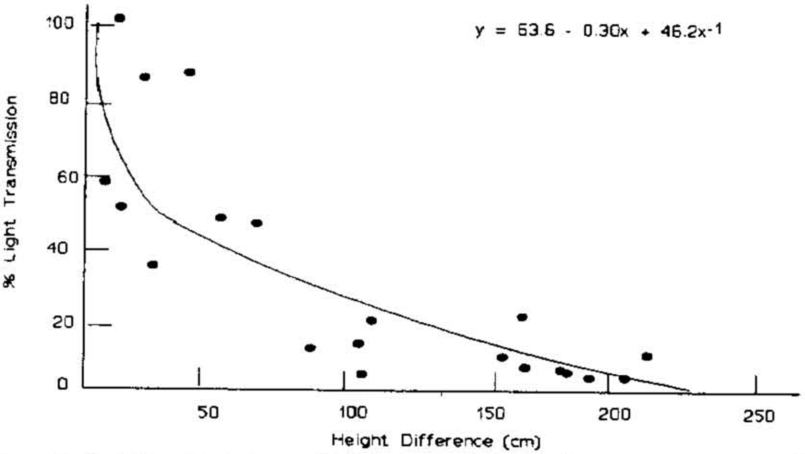


Figure 8. Relationship between % light transmission to the cassava canopy and the difference in height between cassava and *Leucaena* during the first 4 months of cassava growth.

During October 1991, differences in the soil moisture content under the hedgerows and the middle of the alleys indicated that conditions next to the hedgerow were generally wetter when pruning was done every 4 weeks (figure 9). In contrast, unpruned plots generally resulted in drier soils adjacent to the *Leucaena* hedgerow compared to the middle of the alleys. This phenomenon was particularly evident when samples were collected after the last rainfall.

4. Discussion

Pruning the *Leucaena* hedgerows only at the time of maize harvest reduced maize yield significantly. Cassava root yield was less affected by long pruning intervals, although lateral shoot growth was higher in these treatments. Growth characteristics of both crops were influenced by pruning intervals, but not consistently. Distance between the crop and the hedgerow affected both yield and growth characteristics. Although the effects varied with crop and year of experiment, growth responses and yield declines in both years were more attributable to light limitations, while soil moisture showed no clear relationship to different pruning intervals.

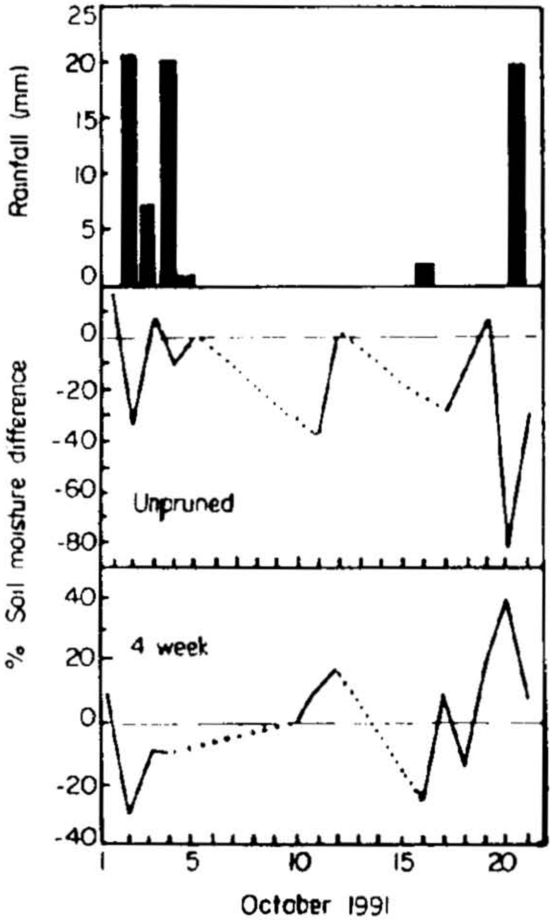


Figure 9. Differences in gravimetric soil moisture content adjacent to *Leucaena* hedgerows and middle of the alleys in the 4-week pruning and unpruned plots during the month of October 1991.

It is well known that shade decreases maize yield. Mbewe and Hunter (1986) observed a decrease in maize grain yield when light to the crop was reduced by 65% during its reproductive stage. Apparently environmental stress before and during flowering reduces grain number and total grain yield. Kiniry and Ritchie (1985) showed that shade stress during the grain filling period significantly reduced kernel number and grain yield. Johnson and Tanner [In: Nesmith and Ritchie 1992] showed that yield reductions were significant after the 8 week pruning in 1992 and 10 week pruning in 1991, suggesting that shading has detrimental effects between 8-10 WAP and harvest. Ten weeks approximately mark the beginning of the grain filling period. Delaying hedgerow pruning to 10 WAP affects maize grain yield in plants grown adjacent to the hedgerows. This underlines the importance of environmental effects at this stage in maize growth. As Schussler and Westgate

(1991) observed, shading during the grain filling period had a more marked effect on kernel loss than shading during pollination. Since the upper maize canopy contributes a large portion of its assimilates to the cob, reduced photosynthetic capacity will lead to fewer and lighter kernels and consequently lower total grain yield [Edmeades and Daynard 1979]. Fewer kernels and lower kernel weight under unpruned *Leucaena* in 1992 accounted for the reduced grain yield observed in this experiment.

Maize stover yield was less affected by the pruning interval than grain yield. Stover was reduced by 30% in unpruned plots compared to pruned treatments in 1992. Mbewe and Hunter (1986) observed similar reductions (25%) in stover yield when shade was applied either at the vegetative stage or during grain filling, but found no differences when plants were shaded during the reproductive period. Generally, maize grain yield exhibits a stronger response to limited solar radiation than stover yield [Scarsbrook and Doss 1973]. A less sensitive response by stover production to light limitations, in conjunction with high stover yield variability, may explain why no difference was observed in the first year of the experiment.

Maize plants adjacent to *Leucaena* hedgerows were shorter with smaller diameters than those in the middle of the alleys. Etiolation was expected under the shade of *Leucaena*. However, shading for the first 4 weeks after planting may have reduced the growth of assimilates enough to suppress vertical growth, thereby allowing the plants in the middle of the alleys to grow taller [Tetio-Kagho and Gardner 1988]. A reduction in assimilates could also explain why leaf area did not differ significantly under different pruning intervals.

Reduced light transmission to maize had detrimental effects on maize growth and final yield. Similar findings were also reported by Lawson and Kang (1990) who associated decreased maize yields with increased *Leucaena* biomass and excessive shading by the hedgerows. Shade was considered the most important factor in low maize yields under *Acacia albida*, where hedgerows were pruned only once during the growing season [Bama and Getahun 1991]. Light transmission gradients increase as the distance from the hedgerow increases, especially when *Leucaena* hedgerows were pruned at long intervals [Kang et al. 1985].

Were reduced light conditions solely responsible for the observed decline in maize yield? Another possible limiting factor, soil moisture, did not exhibit any clear trends during the maize cropping season. Nevertheless, other studies indicate that extended drought during the growing season, particularly at the time of grain-filling could seriously decrease yield [Nesmith and Ritchie 1992, Schussler and Westgate 1991]. Competition for water was unlikely in these trials since the soil water requirements of maize are generally satisfied during the main cropping season under rainfed systems as observed in southwestern Nigeria.

Cassava productivity was not notably affected by any pruning interval in either year. Observed early growth differences between unpruned and pruned plots suggest that continuous shading, i.e., beyond 10 weeks after planting, would be reflected in a decrease in total yield. Cassava etiolated under longer pruning intervals (8 - 10 weeks) until the crop outgrew the hedgerow and shade no longer inhibited vegetative growth; etiolation continued when *Leucaena* was not pruned. Kasele (1983) related a decline in cassava dry matter yield to increased height and a concurrent decrease in stem diameter with increasing shade. Since cassava partitions assimilates to root and shoot simultaneously, a greater proportion of assimilates are diverted to shoot growth under limited light conditions [Splittstoesser and Tenya 1988]. There was a significant increase in lateral shoot yield where pruning was delayed or neglected.

The effect of soil moisture on cassava productivity could not be established for pruning intervals of 10 weeks or less. Higher soil moisture in the middle of the alleys in unpruned plots may be due to an 'umbrella' effect caused by the nature of the *Leucaena* hedgerow canopy. Wetter conditions adjacent to *Leucaena* hedgerows under the 4-week pruning interval may be the result of moisture conservation by shading of the hedgerows, a suggestion also made by Kang and Lawson (1990). However, the soil moisture pattern in the unpruned plots at the end of the rainy season (5 months after planting) suggests the possibility of soil moisture depletion. Indeed, Baker et al. (1989) working in Australia observed that cassava yield was markedly reduced when the plant experienced drought stress at 6-8 months. Others have found that prolonged moisture stress can result in reductions in total biomass and root yield [El-Sharkaway et al. 1992].

On the basis of this study, recommendations for *Leucaena* hedgerow pruning can only be made with respect to maize. Delaying pruning beyond 10 weeks after the initial cut back caused a decline in maize yield attributable to shading during the grain-filling stage. Timely pruning at 10 weeks after planting maize is therefore advisable, in order to maintain crop productivity and to derive the benefits of alley cropping. The effects of delayed pruning (i.e., more than 10 weeks) on cassava root yield need to be investigated further in order to recommend a pruning interval that optimizes both maize and cassava yields.

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