Hedgerow Pruning Effects on Light Interception, Water Relations and Yield in Alley-Cropped Maize

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ABSTRACT. In alley cropping, trees and crops compete for light, nutrients, and water. However, there is little information on how hedgerow pruning would impact light interception, water relations, and yield in a maize (*Zea mays* L.)–mimosa (*Albizia julibrissin* Durazz) alley-cropping system. Competition between mimosa hedgerows and maize was measured under alley cropping on a compass loam sand in Shorter, AL. Treatments were established in a randomized complete block design and consisted of no pruning or pruning at 30, 30 + 60 and 30 + 90 days after maize planting (DAP) and at 5 cm and 50 cm pruning heights. To minimize competition for nutrients, 189 kg N ha^{-1}, 9 kg P ha^{-1}, and 73 kg K ha^{-1} were applied. Reduction in photosynthetically active radiation (PAR) was assessed periodically. Water status in maize was assessed using a steady state porometer to measure maize leaf stomatal conductance and transpiration rate. PAR was lower in maize rows closest to hedgerows (ROW1) than in second maize rows from hedgerows (ROW2)

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especially after 60 DAP. After the 90 DAP pruning, 30 + 90 DAP pruning treatment gave significantly lower stomatal conductance (CD) and transpiration rate (TR) in maize leaves than did 30 DAP or 30 + 60 DAP treatments. ROW1 had high CD and TR, which suggests greater water loss that might reduce final yields. Pruning increased PAR, maize grain and stover yields compared to no-pruning plots. Pruning twice gave higher grain and stover yields than did no-pruning controls. Pruning at 5 cm height gave higher maize yield than pruning at 50 cm. On average, ROW1 had 24% lower yield than did ROW2. Interaction of treatment by row was highly significant. Yield in ROW1 was more affected by pruning treatments than in ROW2. After 90 DAP, 30 + 90 DAP pruning treatment had lowest shade, followed by pruning treatment 30 + 60 DAP at 5 cm height. Pruning at 90 DAP and pruning at 5 cm height reduced competition for water and light. Hedgerow pruning can increase light interception and reduce water stress in the maize crop. doi:10.1300/J064v31n04_08

KEYWORDS. Alley cropping, competition, conductance, mimosa, maize, photosynthetically active radiation, transpiration rate

INTRODUCTION

Alley cropping or hedgerow intercropping is an agroforestry practice in which perennial, preferably leguminous, trees or shrubs are grown simultaneously with an arable crop. The trees, managed as hedgerows, are grown in wide rows and the crop is planted in the interspaced or "alley" between the tree rows (Kang and Gutteridge, 1998). Alley cropping has been widely promoted in the many parts of the world, especially in the tropical areas. As practiced in the tropics, the trees are generally heavily pruned, and the leaves and small stems are applied to the soil as mulch, thus serving as a source of N and organic matter. Benefits of alley cropping include improvements in N fertility and other soil properties, enhanced weed control maintenance of soil organic matter, and maintenance crop productivity over time. On sloping land, hedgerows act as a physical barrier to slow runoff and reduce soil loss. In addition, secondary products of alley cropping, such as forage, firewood and reduced reliance on chemical fertilizers and pesticides contribute to economic and environmental sustainability.

Alley cropping is a simultaneous and dynamic system wherein both crop and tree are continually changing in response to environmental conditions and management that affect both the trees and crops. The effectiveness of a simultaneous system such as alley cropping depends on the successful management of competition for light, nutrients and water between woody species and crops (Kang and Shannon, 2001).

Competitive interactions for resources (water, light, and nutrients) between the tree component and crops in alley-cropping systems have been documented in a variety of practices (Cannell et al., 1996; Akonde et al., 1996; Tilander and Ong, 1999). Plants require light, nutrients and water for their growth and survival; trees, crops and weeds have the same requirement in this regard. Thus, hedgerow trees, just like weeds, can compete with companion crops for available light, nutrients and water in an alley-cropping system. Tree-crop competition is often believed to be responsible for declining crop yields at the hedgerow-crop interface commonly observed in many alley-cropping trials (Singh et al., 1989; Fernandes, 1990; MacLean et al., 1992). Studies on tree-crop competition in alley cropping have mostly focused on indirect competition through exploitation of shared resources (MacLean et al., 1992). Many trials report low yields of crops grown adjacent to hedgerows that negate the benefits from yield increases in the center of the alleys (Kang and Shannon, 2001). This usually is a sign that the pruning regime was not adequate to control competition from the hedgerows (Kang and Shannon, 2001). Reducing the interval between prunings during early crop growth may be all that is needed to reduce the competition at the tree-crop interface to a tolerable level (Shannon et al., 1994; Korwar and Radder, 1994; Tilander et al., 1995). With alley cropping, timely hedgerow pruning is essential to reduce the effect of shading on performance and yield of the companion crops. The optimum pruning regime is not a fixed interval throughout the year. Pruning should be timed to minimize competition for moisture, nutrients, and light during the critical periods of crop growth, while maximizing conditions for hedgerow regrowth during crop senescence and the dry season to maximize biomass availability for the succeeding crop (Kang and Shannon, 2001). Isaac et al. (2004) found that 3 prunings per maize crop gave higher yields than 2 prunings.

Competition for solar radiation is the most prominent aboveground competition between hedgerow trees and companion crops. In Nigeria, Kang et al. (1985) measured radiation incident on crop rows as a function of distance from the hedgerows to determine the extent of shading by shrubs. The maize rows adjacent to leucaena (*Leucaena leucocephala*) received 51-69% of the available light compared with 75-81% received by mid-alley rows. Lawson and Kang (1990) observed that maize yield decreased with increased total dry matter yield of pruning from the associated hedgerow species. Maize grain yield was positively correlated with light transmission incident on maize at cob height. Yield with 2 m spacing between hedgerows was lower than that with 4 m spacing, due to greater shading of maize at the narrow spacing.

Hedgerow shoot pruning can alleviate shading of crops while providing biomass for mulch or green manure. Duguma et al. (1988) showed that less frequent pruning and higher pruning height increased hedgerow biomass yields, but at the same time reduced the companion crop yield. Shading can be minimized by more frequent pruning and lower pruning height, but this also limits hedgerow capacity for biomass production and nutrient recycling (Kang, 1993).

Hedgerow tree roots can compete with crop roots for available water and nutrients in the topsoil. In semi-arid India, significant water competition was observed between leucaena hedgerows and castor (*Ricinus communis*), cowpea (*Vigna unguiculata*), and sorghum (*Sorghum bicolor*) (Singh et al., 1989). In southwestern Nigeria, Verinumbe and Okali (1985), using root barriers and root pruning to assess competition between maize and coppiced teak trees (*Tectona grandis*) found that shading alone depressed maize yield by 40%, while shading and root competition combined depressed yield by more than 60%. At a drought-prone site in Haiti, alley cropping gave significantly higher maize yields than the control without hedgerows when rainfall was adequate despite the reduced cropping area, but under extreme drought conditions, yields in the alleys differed little from the control (Shannon et al., 2003). In the Guinea savanna of Congo, yield depression in the drought-prone short rainy season was less in the alley plots than in control plots, suggesting that improved moisture and fertility conditions in alley plots were more important than the competitive effect of leucaena (Shannon et al., 1994). Under drought stress conditions, higher groundnut yields in *G. sepium* alleys than in control plots were attributed to shading that reduced evapotranspiration in the crop (Schroth et al., 1995).

Shoot prunings also affect hedgerow root systems. Schroth and Zech (1995) reported that shoot pruning of *G. sepium* during the cropping period shifted the peak for maximum root development to the dry season, thereby reducing the competitiveness of *G. sepium* in alley cropping. Regular shoot prunings of the leucaena hedgerows over 4 years significantly reduced both the fine root density (61%) and leucaena root diameter size as compared to unpruned hedgerows (Akinnifesi, 1995). Regular removal of leucaena prunings also reduced root density by 21% in 4 years. There was also a reduction in fine root proliferation of leucaena in the top 100 cm of the soil profile when alley cropped with maize for eight seasons compared to unpruned trees in the fallow plot. Shoot pruning of *Prosopis juliflora* in semi-arid Nigeria resulted in higher soil moisture content and fewer tree roots in alleys cropped to sorghum compared to alleys in which *P. juliflora* hedgerows were unpruned (Jones et al., 1998). Korwar and Radder (1994) reported that increasing the interval between prunings from 1 to 6 months resulted in increased moisture competition and decreased sorghum yield. In Ohio, black locust (*Robinia pseudoacacia*) hedgerows depleted the adjacent soil water after irrigation, but there was no evidence of competition from hedgerow roots on maize grain yield unless soil water content declined because of drought (Ssekabembe et al., 1994).

Although the above studies suggest pruning of hedgerows reduces competition for water, direct evidence was lacking to show that it was possible to improve (1) the water relations in the crop by pruning the associated hedgerow; (2) soil water relations by pruning the leaves from the tree but leaving the roots intact within the plot area. It was hypothesized that competition for light and water could be managed by pruning the hedgerows to reduce utilization of these factors by the trees. An experiment was conducted to examine the effect of different pruning regimes and pruning height on competition between mimosa (*Albizia julibrissin* Durazz.) hedgerows and maize (*Zea mays* L.) in an alley-cropping system in central Alabama. The objectives were: (1) assess the effect of hedgerow pruning on maize leaf water relations, (2) assess the effect of pruning regime on light penetration into the maize canopy, and (3) assess under field conditions the effects of hedgerow pruning regime on maize grain and biomass yields in an alley-cropped maize system.

MATERIALS AND METHODS

Site Description

The study was carried out in an alley-cropping system with mimosa as hedgerow and maize as crop, at EV Smith Field Crop Research Unit in Shorter, Alabama (32°42′ N, 86°54′ W). The soil was a Compass loamy sand (coarse-loamy, siliceous, subactive, thermic Plinthic Paleudults) with 82% sand, 13% silt, 5% clay, 4.6 $\mathrm{cmol_c kg^{-1}}$ soil CEC, 6.7 g organic matter kg^{-1}soil and pH (H_2O) 6.0. Mean annual maximum temperature was 23.4°C; mean annual minimum temperature was 10.3°C. The annual rainfall recorded over a thirty-year period averaged 1,388 mm.

Site Preparation

Soil tillage was done twice by a field cultivator during the crop season. The first soil preparation took place approximately 15 days before maize seed planting and an inter-row tillage was done about 20 days after maize seed planting. The herbicide mixture of 2,4-D amine and glyphosate were applied at the rates of 1 pt/ac (0.56 kg a.i. ha^{-1}) and 2 pt/ac (5.0 kg a.i. ha^{-1}), respectively with a shielded sprayer on March 21, 2003 to control cool season grasses. At one day after maize seed planting, *S*-metolachlor (Dual-2 Magnum) was sprayed at 1 pt/acre (2.14 kg a.i. ha^{-1}) and atrazine at 1.5 qt/acre (3.36 kg a.i. ha^{-1}).

Hedgerows

The experiment was imposed on existing hedgerows that had been used in a completed study on mimosa hedgerow establishment. Paired hedgerows of mimosa were established in April 2002 and were about 12 months old at the start of this experiment. The original layout consisted of 3 blocks and 18 plots. There were 6 pairs of hedgerows 13.2 m long in each block. Hedgerows were 1.5 m apart, with 7.7 m wide between pairs of hedgerow. Two of the paired hedgerows in each block had been pruned to 5-10 cm height and four left uncut.

Experimental Design

In order to test the hypothesis that hedgerow pruning reduced competition for water and light, it was necessary to compare conditions in plots in which hedgerows were pruned with conditions in plots in which hedgerows were not pruned. The experiment was designed in consideration of the existing layout of hedgerows and the prior pruning treatment of the hedgerows. Because some of the hedgerows had previously been pruned at 5-10 cm height, while other hedgerows were unpruned, it was decided to prune hedgerows at two heights, 5 cm and 50 cm. Because of the random occurrence of pruned hedgerows within blocks, it was necessary to create plots centered on individual pairs of hedgerows. A slit was made 76 to 88 cm deep in the soil using a tractor-mounted shank to separate the plots and cut any tree roots that might have entered into adjacent plots. The slit was completed approximately 28 days before maize seed planting.

The experiment design was a randomized complete block with three replications. The six pruning treatments applied to the mimosa were: (1) no-pruning control; (2) pruning at 30 days after planting maize (DAP) to 50 cm height; (3) pruning at 30 + 90 DAP to 50 cm height; (4) pruning at 30 + 60 DAP to 50 cm height; (5) no-pruning control originally pruned to 5 cm height; (6) pruning at 30 + 60 DAP to 5 cm height.

The first pruning took place on May 30 and 31, 2003, on mimosa hedgerows of approximately 1.6 m and 1.1 m in height. The second pruning was delayed due to heavy rains for two days and took place on July 2, 2003. The third pruning time was July 29, 2003. Leaves and stems from each pruning were applied as mulch in the maize rows. Samples of leaves and stems were taken and oven dried (60°C for 48 hours) for dry matter determination. Samples were ground to pass a 1 mm mesh screen and analyzed for total N and C using LECO CHN-600 analyzer (LECO Corp., St. Joseph, MI).[1] Hedgerow height was measured before and after each pruning.

Maize Crop

Maize seeds were sown on April 29, 2003. The planting density was 45,343 plants ha^{-1} assuming a full stand of maize. There were 112 kg ha^{-1} of 34-0-0 compound fertilizer consisting of 38 kg ha^{-1} of N; 123 kg ha^{-1} of 17-17-17 compound fertilizer, giving 21 kg ha^{-1} of N, P_2O_5 and K_2O, respectively; and 67 kg ha^{-1} of 0-0-60 fertilizer consisting of 40 kg ha^{-1} of K_2O applied to the maize in bands at planting. On June 13, 2003, 56 kg ha^{-1} 34-0-0 was applied again because the maize was chlorotic. It is assumed that N applied previously had leached out of the maize rooting zone as a result of excessive rainfall. Total nutrients applied consisted of 189 kg N ha^{-1}, 9 kg P_2O_5 ha^{-1} and 73 kg K_2O ha^{-1}, respectively. Six rows of maize were planted between each pair hedgerows; maize row-to-row distance was 75 cm. The distance between the hedgerows and the first maize rows was 122.5 cm. The plots were configured to center on a pair of hedgerows. Thus, each plot had three maize rows at the east side and three maize rows at the west side.

Maize was harvested row by row on September 4 and 5, 2003. Measured maize harvested density was 43,817 plants ha^{-1}. Harvest area per row was 6 m by 0.75 m. Data recorded at harvest included grain yield (adjusted to 13% moisture), fresh weight of ears, fresh weight of stover, number of ears harvested, and maize height. Maize yield was calculated for each row based on 75 cm row spacing.

Maize Leaf Water Relations

Maize leaf stomatal conductance and transpiration were measured weekly with a LI-1600 Steady State Porometer (LI-COR Inc., Lincoln, NE) beginning June 12, 2003 after 1st pruning. In each plot, the first and second rows on either side of hedgerow were measured; three readings from the uppermost leaf were taken from each maize row. Data were collected on a handheld palm pilot device and then downloaded to a computer. Measurements were taken in the morning; therefore, the east side of hedgerows received direct sunlight, while the west side was in shade.

Light Interception

In order to measure the light interception of maize leaf, a LI-189 Light Meter (LI-COR Inc., Lincoln, NE, USA) was used to determine the reduction in Photosynthetically Active Radiation (PAR). In each plot, PAR was measured in the open space adjacent to the plots at about 145 cm height and then at the height of the uppermost leaves. Six observations were made per row in the first and second rows on either side of the hedgerows. At the time of the first measurements, the uppermost leaves were at approximately 120 cm height, thus PAR readings in maize rows were taken at 120 cm height. At the later measurements, the maize plants were taller, but not of uniform height; thus measurement height varied with row and treatment position. PAR measurements were taken once a week. Reduction in PAR in the maize rows was calculated as a percentage based upon the measurement in the open space.

Data Analysis

Maize grain and stover yields, mimosa biomass, mimosa total N and C data were analyzed by analysis of variance using the General Linear Model (GLM) procedure provided by the Statistical Analysis System (SAS, 1999). PAR and maize leaf stomatal conductance and transpiration data were analyzed by using Mixed-model following a split block design. All main effects and their interactions were determined using F-tests. Single-degree-of-freedom contrasts were used to test difference among the treatments. Unless indicated otherwise, all tests were done at $\alpha = 0.05$ level.

RESULTS AND DISCUSSION

Rainfall Condition

The total rainfall for growing season was 605.8 mm from planting (April 29, 2003) to harvest (September 5, 2003). Rainfall was generally well distributed during the entire season (Figure 1), which was very unusual for central Alabama. The longest period without rain was 7 days, from June 21 to 27 (several days before silking stage), and from July 25 to 31 (during dough stage). A large rainfall event (52.8 mm) occurred on July 1, which neared the silking stage. Hence, drought stress during silking was not likely to have occurred.

Maize Leaf Water Relations

Porometer measurement was started on June12, 2003. After the 2nd pruning of mimosa at 60 DAP (silking stage in maize), there were no significant differences among the treatments in stomatal conductance (CD) and transpiration rate (TR) for maize leaves, or among maize rows within treatments. This lack of treatment effect on CD and TR might be related to the large amount of rainfall before the 2nd pruning (59.8mm on July 1, 2003; Figure 1).

After pruning at 90 DAP, pruning treatment 30 + 90 DAP at 50 cm height had significantly lower CD and TR than did pruning treatment 30 + 60 DAP at 50 cm height. One degree of freedom contrast showed that pruning at 30 + 90 DAP had significantly lower CD and TR than did pruning at 30 + 60 DAP (Table 1). Differences among the maize rows were highly significant for CD and TR. Maize rows next to hedgerows (ROW1) had higher CD and TR compared to second rows (ROW2) (Figure 2). On east side of the hedgerows, ROW1 had 37% higher CD and 47% higher TR than did ROW2; on west side ROW1 had 28% higher CD, and 23% higher TR than did ROW2. Davies (1986) and Jarvis (1981) found that greater stomatal conductance and transpiration rate resulted in greater water loss and more negative water potential. The resulting water loss might reduce maize final yields. Korwar and Radder (1994) found that pruning of hedgerow shoots reduced competition

FIGURE 1. Rainfall from April through September, 2003 at EV Smith, Shorter, AL, and timing of planting (P), pruning operations (Pr), fertilizer applications (F), tasseling (T), silking (S), and harvest (H) date in relation to rainfall events.

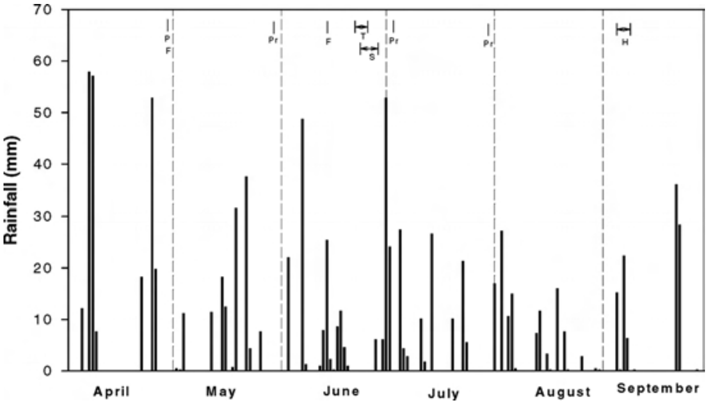


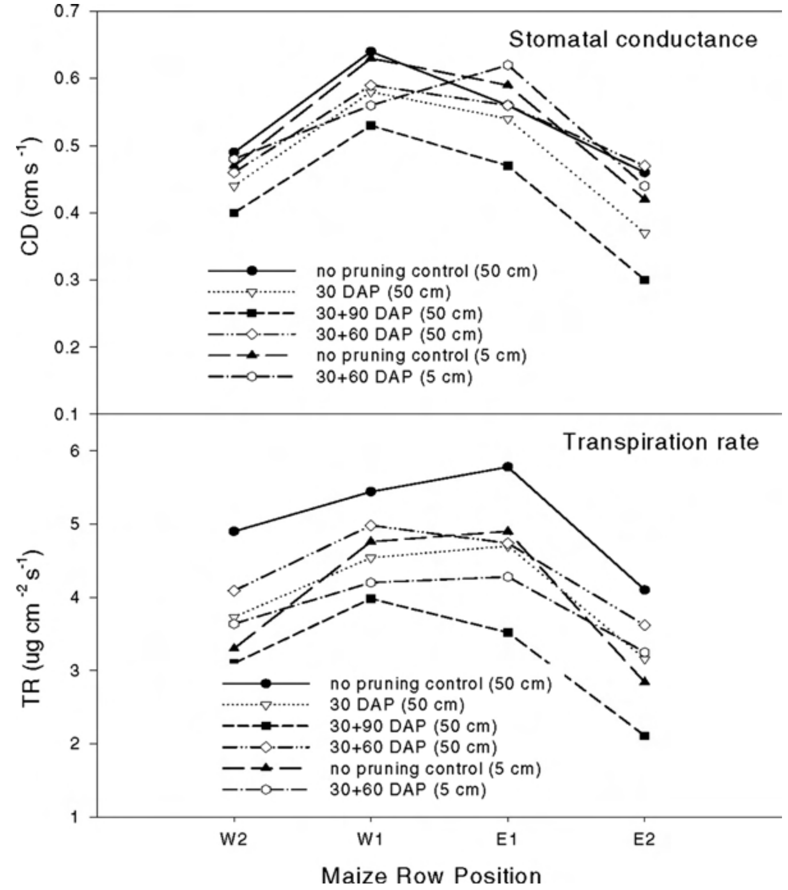
TABLE 1. Effect of pruning treatment on maize leaf water relations after pruning at 90 DAP. Shorter, AL, 2003.

Pruning factor	CD	TR
	$cm.s^{-1}$	$\mu g.cm^2.s^{-1}$
No-pruning control (50 cm)†	0.54	5.06
No-pruning control (5 cm)‡	0.53	4.00
30+60 DAP (pruning at 5 cm)	0.52	3.84
30+60 DAP (pruning at 50 cm)	0.52	4.36
30 DAP (pruning at 50 cm)	0.48	4.03
30+90 DAP (pruning at 50 cm)	0.43	3.17
$LSD_{.05}$	0.09	0.84
CV%	22.2	24.8
Contrast	$Pr > F$	
30+60 DAP vs. 30+90 DAP	0.0448	0.0067
30 & 30+60 DAP vs. 30+90 DAP	0.0610	0.0069

CD = stomatal conductance, TR = transpiration rate.

†Unpruned control for 50 cm pruning height treatments, ‡pruning height at start of experiment.

FIGURE 2. Effect of pruning regime and row position relative to hedgerows on maize leaf water relations after the 3rd hedgerow pruning at 90 days after planting. W = west side of hedgerow, E = east side of hedgerow, 1 = maize row close to tree, 2 = adjacent maize row to 1. Shorter, AL, 2003.



for water by decreasing moisture uptake from the soil by the hedgerows and thereby increased crop yield. Root pruning had a greater effect when the interval between shoot prunings was long, which suggests that frequent shoot pruning at critical periods also reduced hedgerow competition for soil moisture. In our study, we found that the highest yield with pruning to 50 cm of height was with pruning at 30 + 90 DAP, which was the treatment with lowest CD and TR.

Light Interception

Pruning at 30 DAP

Maize light interception was closely related to tree height. Before the 1st pruning, at 30 DAP, mimosa heights showed significant differences (data not shown). The two treatments that were pruned prior to the start of the experiment were shorter than those that were not previously pruned. When averaged over the 6 treatments, reduction in PAR (or shading) varied significantly among rows. PAR was reduced more in the rows adjacent to mimosa (ROW1) than in the second row from the mimosa (ROW2). This is consistent with the findings of Kang et al. (1985). The interaction of treatment by row was not statistically significant. Mean difference for the two controls (no-pruning vs. original pruning at 5 cm height) were highly significant by the F-test. The control that had never been pruned had higher reduction in PAR than the control originally pruned to 5 cm. This indicated strong competition from the hedgerows for light.

After the 1st pruning, differences in reduction in PAR tested highly significant for rows and interaction of treatment by row. On average, reduction in PAR was 30.1% greater without pruning than with pruning in ROW1, but only 6% greater without pruning than with pruning in ROW2 (Table 2).

Pruning at 60 DAP

Before the 2nd pruning date (60 DAP), mimosa heights also showed highly significant differences (data not shown). Statistical differences in PAR reduction occurred among treatments and rows. The contrast of no-pruning controls versus pruning treatments 30 + 60 DAP at the two heights was highly significant. Pruning at 50 cm height gave greater reduction in PAR than did pruning at 5 cm height ($P \leq 0.039$).

After the 60 DAP pruning, reduction in PAR was highly significant for treatments and rows. The controls reduced PAR significantly more than did pruning at 60 DAP at the two heights (Figure 3). Interaction of treatment by row was highly significant. On average in the 2nd pruning, PAR was reduced 61% more in no-pruning treatments than in the pruning treatments in ROW1, but only 50% more in ROW2 (Table 2). ROW1 had 19% more shade than ROW2 in pruned plots, but 51% more shade than ROW2 in no-pruning controls.

TABLE 2. Reduction in photosynthetically active radiation (PAR) by maize row as percentage of total incoming radiation at three pruning dates. Shorter, AL, 2003.

	No-pruning control %	Pruning treatment %	Difference control > treatment %
After pruning at 30 DAP (May 30)			
ROW1[†]	47.0	35.9	30.1
ROW2[‡]	34.2	32.2	6.0
After pruning at 60 DAP (July 2)			
ROW1	47.9	18.7	61.0
ROW2	31.8	15.7	50.2
Before pruning at 90 DAP (July 29)			
ROW1	73.4	50.4	31.4
ROW2	49.5	38.4	22.5

[†]ROW1 = maize row close to hedgerow, [‡]ROW2 = second maize row of hedgerow.

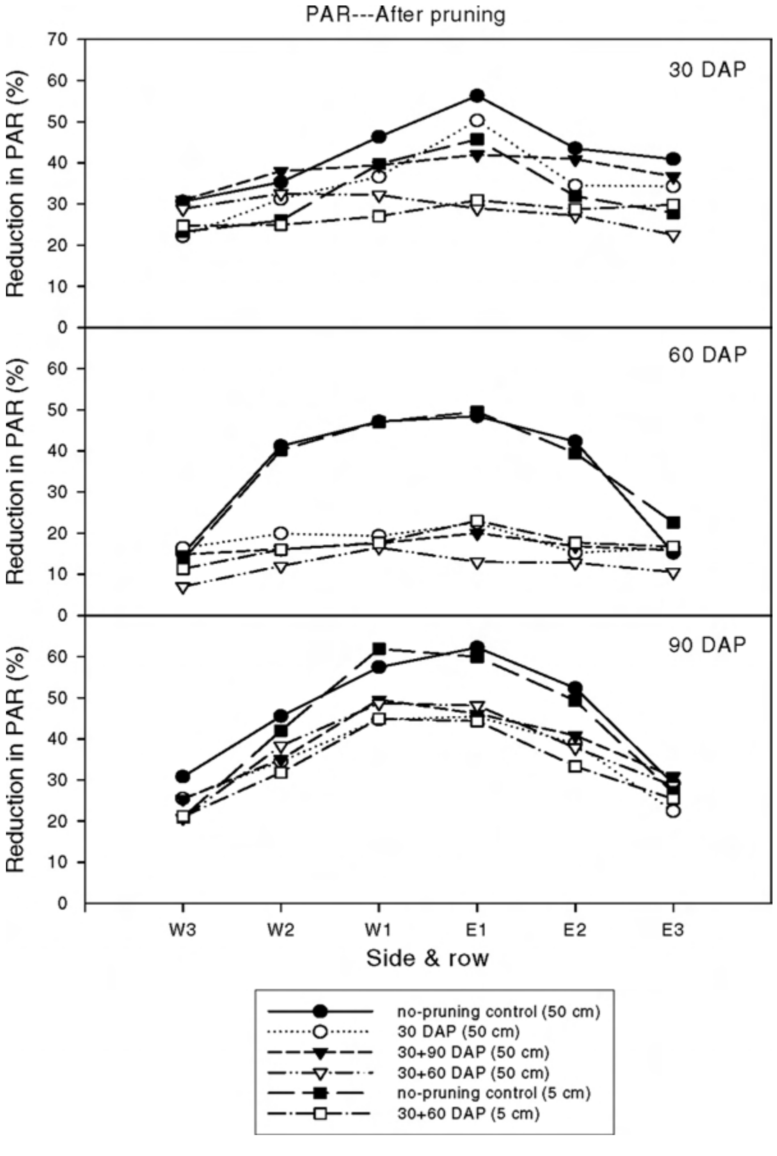
Pruning at 90 DAP

Before the 3rd pruning date (90 DAP), mimosa heights still showed highly significant differences, reflecting previous pruning dates and heights. Statistical differences were observed in PAR reduction in treatments, rows, and interaction of treatment by row. Mean differences for the controls versus 30 + 60 DAP pruning at the two heights were highly significant. The controls had significantly greater reduction in PAR than did the four pruning treatments. On average, reduction in PAR was 31.4% greater without pruning than with pruning in ROW1, and 22.5% greater without pruning than with pruning in ROW2 (Table 2).

After the 90 DAP pruning, reduction in PAR among treatments and rows were highly significant. No-pruning controls had significantly higher reductions in PAR than did pruning 30 + 60 DAP (Figure 3). There were no differences in reduction in PAR between the 30 + 90 DAP pruning treatment and other pruning treatments and no effect of pruning height or between one and two pruning per season on PAR reductions. PAR reduction was greater in ROW1 than in ROW2 (Table 2).

In sum, reduction in PAR available to the maize (shading) was affected at all three dates by pruning treatment and row position with respect to the hedgerows (Figure 3). Before pruning, reduction in PAR of ROW1 and ROW2 were significantly different over the six treatments,

FIGURE 3. Effects of hedgerow pruning regime and maize row position relative to hedgerows on reduction in PAR (shade) incident upon maize after prunings. Shorter, AL, 2003. W = pruning at west side, E = pruning at east side, 1= maize row close to tree, 2 = adjacent maize row to 1, 3 = adjacent maize row to 2.



indicating strong competition for light (data not shown). After pruning, reduction of PAR in ROW1 and ROW2 did not differ among the four pruning treatments, suggesting that light competition was reduced in these treatments. However, in no-pruning controls, reduction in PAR of ROW1 and ROW2 were different, especially at 60 DAP (the 2nd pruning). In other words, hedgerows in no-pruning controls still strongly competed for light. These results further suggested pruning hedgerows reduced competition for light. De Costa and Surenthran (2005) reported that competition for light was a significant factor in reducing tea yields in hedgerow intercrops. Similar observations were made by Miller et al. (2001) and Marshall (1995).

After both the 1st and 2nd prunings, interactions of treatments by row were significant. Pruning had greater effect on ROW1 than ROW2 and pruning reduced the competition for light after pruning. Kang et al. (1985) observed that maize rows adjacent to leucaena received about 60% of the available light compared with 78% by middle rows. This result was also consistent with findings of Mekonnen (1992) who found that maize grain yields in rows adjacent to hedgerows of *L. diversifolia* were reduced by 88% largely due to competition for light.

Maize Yield

Grain and Stover Yields

Maize grain and stover yields were significantly greater in plots where the hedgerows were pruned than in no-pruning plots (Table 3). Highest yields were obtained when hedgerows were pruned at 5 cm height at 30 and 60 DAP and at 50 cm height at 30 and 90 DAP. Lowest grain yields occurred for control plots which had not been pruned prior to the start of experiment. Similar results have been reported by Duguma et al. (1988), who observed higher maize yields with increasing pruning frequency. Highly significant differences were obtained by contrast comparisons of no-pruning controls versus pruning treatments, and the controls versus pruning at 30 + 60 DAP at two heights. Pruning at 90 DAP gave significantly greater grain yield than pruning at 30 + 60 DAP. The 90 DAP pruning occurred during a period of drought stress, which also coincided with grain filling in the maize. Thus the 90 DAP pruning reduced moisture stress during a critical growth stage in the maize. Pruning at 5 cm height gave greater grain yield than at 50 cm height.

Maize grain and stover yields in ROW1's were lower than those in ROW2's (Figure 4). Friday and Fownes (2002) found that grain yield

TABLE 3. The effect of hedgerow pruning regime on maize yields. Shorter, AL, 2003.

Pruning factors	Pruning height	Grain yield	Stover yield
	cm	kg ha^{-1}	
30 + 60 DAP	5†	10,070	5,590
30 + 90 DAP	50‡	9,500	5,580
30 DAP	50	8,780	5,120
30 + 60 DAP	50	8,240	4,780
No-pruning control	5	6,220	4,580
No-pruning control	50	5,230	3,580
LSD $_{.05}$		1,225	1,119
CV%		18.5	25.9
Contrast		Pr>F	Pr>F
50 cm vs. 5 cm for no-pruning		0.1108	0.0752
Control vs. 30 + 60 DAP at 50 cm and 5 cm		0.0001	0.0001
50 cm vs. 5 cm for 30 + 60 DAP		0.0045	0.0559
1 pruning vs. 2 prunings at 50 cm		0.8659	0.8773
30 + 60 DAP vs. 30+ 90 DAP at 50 cm		0.0451	0.3781
2 controls vs. 4 treatments		0.0001	0.0001

†Original pruning height, ‡unpruned control for 50 cm pruning treatments.

was severely depressed in rows adjacent to the hedgerows in the alley crop. Many other studies also showed that the yield of crop plants adjacent to the hedgerows was lower than in the centre of the alley (De Costa et al., 2005; Huxley et al., 1989; Karim, 1987; Kass et al., 1986; Miller et al., 2001; Singh et al., 1989; Wanvestraut et al., 2004; Yamoah et al., 1986). The interaction of treatment by row was significant. Maize grain yield was 56% lower without pruning than with pruning in ROW1, but only 21% lower in ROW2 (Table 4). The row effect on grain yield was more prominent in unpruned plots than in pruned plots. For maize stover, there was no significant difference for interaction of treatment by row, but stover yield was 33% lower without pruning than with pruning in ROW1, and 13% lower in ROW2 (Table 5; Figure 4).

FIGURE 4. Maize grain and stover yields as affected by hedgerow pruning regimes and maize row position relative to hedgerows. W = west side of hedgerows, E = east side of hedgerows; 1 = maize row next to hedgerow, 2 = maize row next to row 1. Shorter, AL, 2003.

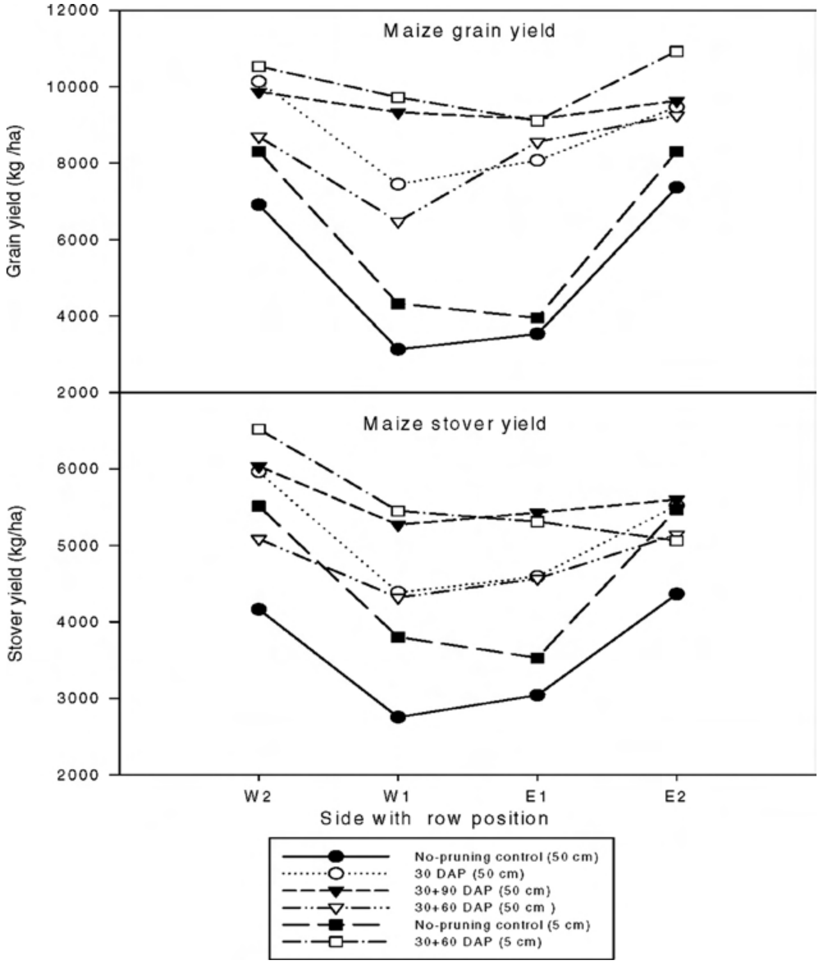


TABLE 4. Maize row position and pruning effects on grain yield. Shorter, AL, 2003.

Maize row position	Maize grain yield		Percent reduction in maize yield in control compared to pruned treatments (%)
	No-pruning control (kg ha^{-1})	Pruning treatments (kg ha^{-1})	
ROW1†	3,732	8,483	56
ROW2‡	7,721	9,812	21

†ROW1 = maize row close to hedgerow, ‡ ROW2 = adjacent maize row of ROW1.

TABLE 5. Maize row position and pruning effects on stover yield. Shorter, AL, 2003.

Maize row position	Maize stover yield		Percent reduction in maize yield in control compared to pruning treatments (%)
	No-pruning control (kg ha^{-1})	Pruning treatments (kg ha^{-1})	
ROW1†	3,281	4,916	33
ROW2‡	4,880	5,616	13

†ROW1 = maize row close to hedgerow, ‡ROW2 = adjacent maize row of ROW1.

Mimosa Biomass Yield, C and N Concentration

Mimosa Biomass

Effects of hedgerow pruning treatments on biomass yield are shown on Table 6. All pruned treatments were harvested for biomass at 30 DAP. The hedgerow biomass yields at the second biomass harvest, at 60 DAP, were lower than at the first biomass harvest at 30 DAP. Pruning at 90 DAP produced more biomass than pruning at 60 DAP because of the longer regrowth period with harvest at 90 DAP instead of 60 DAP. Pruning treatment 30 + 90 DAP at 50 cm ranked highest for total biomass yields over the season, but differences did not test significant (Table 6).

There was an inverse relationship between maize yields (Table 3) and mimosa biomass yields (Table 6); maize yields were lower in treatments in which hedgerow biomass yields were higher. Similar results were obtained by De Costa and Surenthran (2005) on the tea alley cropped with six different tree species.

TABLE 6. Hedgerow leaf and stem biomass at three harvested dates. Shorter, AL, 2003.

Pruning regime	1st pruning (30 DAP)		2nd pruning (60 DAP)		3rd pruning (90 DAP)		Total biomass yield	
	Leaf	Stem	Leaf	Stem	Leaf	Stem	Leaf	Stem
	kg ha^{-1}							
30 DAP at 50 cm	4,116	3,299	N/A	N/A	N/A	N/A	4,116	3,299
30 + 60 DAP at 50 cm	3,078	2,144	899	236	N/A	N/A	3,977	2,380
30 + 90 DAP at 50 cm	3,086	2,168	N/A	N/A	2,901	1,742	5,987	3,910
30 + 60 DAP at 5 cm	2,340	1,097	850	266	N/A	N/A	2,773	1,363
Average of biomass	3,051	2,177	875	251	2,901	1,742	4,213	2,738
Significance (F-test)	NS	NS	NS	NS			NS	NS
$LSD_{.05}$	3,654	3,746	1,104	428			4,062	3,672
CV%	58	86	36	49			46	67

NS = Not significant at 0.05 level of probability.

Mimosa Total N and C Contents

Hedgerow total N and C contents were calculated based upon hedgerow biomass yield and total C and N concentrations (Table 7). At the 1st pruning, there were no significant differences for N and C contents. However, lowest N and C yields were obtained by the treatment pruned at 5 cm height, probably because the trees were shorter at the start of the experiment. At the second harvest, there were no differences in total N and C contents due to pruning height. Pruning at 90 DAP (the 3rd pruning) produced more total N and C yields than pruning at 60 DAP (the 2nd pruning). Over the growing season, the 30 + 90 DAP pruning treatment ranked highest for N yield, but differences did not test significant. The 90 DAP pruning treatment had 30 days more for regrowth to occur than when the second pruning occurred at 60 DAP, so it had higher biomass total N and C contents than the latter.

CONCLUSIONS

In this field study, hedgerow pruning treatments increased light interception by maize, and thereby reduced the competition for light between maize and hedgerows. Pruning at 90 DAP decreased CD and TR

TABLE 7. Hedgerow biomass total nitrogen (N) and carbon (C) contents at each harvest as affected by pruning regimes. Shorter, AL, 2003.

Time of Pruning	Treatment	Leaf		Stem		Total	
		N	C	N	C	N	C
		kg ha^{-1}					
30 DAP	30 DAP (50 cm)	148	1927	48	1553	196	3480
	30 + 60 DAP (50 cm)	116	1475	32	1025	148	2499
	30 + 90 DAP (50 cm)	107	1441	28	1011	135	2452
	30 + 60 DAP (5 cm)	84	1083	19	508	104	1591
60 DAP	30 + 60 DAP (50 cm)	11	406	11	107	22	513
	30 + 60 DAP (5 cm)	13	386	13	121	26	507
90 DAP	30 + 90 DAP (50 cm)	84	1671	35	960	119	2631
Total for each treatment			N			C	
	30 DAP (50 cm)		196			3480	
	30 + 60 DAP (50 cm)		170			3012	
	30 + 90 DAP (50 cm)		254			5083	
	30 + 60 DAP (5 cm)		130			2098	
	LSD		155 ns			3018 ns	
	$CV_{.05}$		46			49	

ns = Not significant at 0.05 level of probability.

in maize, which suggests that pruning also reduced the competition for water between maize and hedgerows. Hedgerow pruning treatments increased maize grain and stover yields. Shading and water competition were most evident in the row closest to the hedgerows. Consequently, pruning had the greatest effect on increasing light interception, reducing CD and TR and increasing maize grain and stover yield in the row closest to the hedgerow compared to the adjacent maize rows. Pruning at 30 + 90 DAP to 50 cm height resulted in highest maize grain and stover yields, and reduced competition for water between maize and hedgerows as compared to pruning treatment 30 DAP or 30 + 60 DAP during a phase critical to maize yield. Highest mimosa leaf and stem biomass and N content were obtained with pruning at 30 + 90 DAP, and highest C content was obtained with pruning at 30 DAP. Pruning at 5 cm height also reduced shading and increased yield compared to pruning at 50 cm height.

This research demonstrates the importance of hedgerow management in alley cropping. By manipulating time and number of hedgerow prunings and pruning height, it was possible to reduce competition for light and water and to decrease water stress in the crop, thereby increasing crop yield. More research is needed to assess the effects of hedgerow pruning on water relations in the crop under conditions of drought stress.

NOTE

1. Mention of a company or trade name does not imply endorsement by Auburn University or USDA Agricultural Research Service to the exclusion of others.

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