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GROWTH, BIOMASS PRODUCTION AND DISTRIBUTION OF THREE MULTIPURPOSE TREE SPECIES IN AN AGROFORESTRY SYSTEM AS AFFECTED BY PRUNING

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MIAH, M.G., ARAGON, M.L. & GARRITY, D. P. 1997. Growth, biomass production and distribution of three multipurpose tree species in an agroforestry system as affected by pruning. This paper presents the results of an experiment to assess the growth, biomass production and distribution pattern of three multipurpose tree species (*Acacia mangium, A. auriculiformis* and *Gliricidia sepium*) grown alone and in association with rice and mungbean under pruned and unpruned conditions. The experiment was laid out in July 1990 and concluded in August 1992. The two-year comparative study of tree species showed that *Acacia mangium* attained the highest height (7.6 m), diameter (12.1 cm), and stem dry biomass (17 141 kg ha^{-1}) while *A. auriculiformis* produced the highest leaf (12 465 kg ha^{-1}), branch (16 368 kg ha^{-1}) and total biomass (43 935 kg ha^{-1}) among the unpruned treatments. Intercropping annual crops with the trees had no significant effects on the performance of any of the tree species, but tree branch pruning had a significantly negative effect in all the tree parameters studied. The total biomass in pruned trees was 27-39% lower than that in unpruned trees at the age of two years. Tree species differed substantially in biomass distribution pattern among their constituent parts which might be due mainly to species differences.

Key words: MPTS - growth - biomass production - biomass distribution - tree pruning - annual crops

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MIAH, M.G., ARAGON, M.L. & GARRITY, D. P. 1997. Pertumbuhan, pengeluaran biojisim dan taburan tiga spesies pelbagai guna dalam sistem perhutanan tani akibat pemangkasan. Kertas kerja ini menunjukkan keputusan uji kaji untuk mentaksirkan pertumbuhan, pengeluaran biojisim dan pola taburan tiga spesies pokok pelbagai guna (*Acacia mangium, A. auriculiformis* dan *Gliricidia sepium*) ditanam secara bersendirian dan juga bercampur dengan beras dan kacang hijau di bawah keadaan yang dipangkas dan tidak dipangkas. Kajian dijalankan pada bulan Julai 1990 dan ditamatkan pada bulan Ogos 1992. Kajian perbandingan selama dua tahun bagi spesies pokok menunjukkan *Acacia mangium* mencapai ketinggian yang paling tinggi (7.6 m), diameter (12.1 cm) dan biojisim kering batang (17 141 kg ha^{-1}) manakala *A. auriculiformis* mengeluarkan daun yang paling banyak (12 465 kg ha^{-1}), dahan (16 368 kg ha^{-1}) dan jumlah biojisim (43 935 kg ha^{-1}) bagi spesies yang dipangkas. Penanaman selang bagi tanaman dengan pokok tersebut tidak memberi kesan yang bererti terhadap prestasi mana-mana spesies tersebut. Bagaimanapun, pemangkasan dahan memberi kesan negatif yang bererti terhadap semua parameter pokok yang dikaji. Jumlah biojisim dalam pokok yang dipangkas ialah sebanyak 27 - 39% lebih rendah daripada pokok yang tidak dipangkas pada umur dua tahun. Spesies pokok berbeza sebahagian besarnya dalam pola taburan biojisim bagi komponennya yang mungkin kebanyakannya disebabkan oleh perbezaan spesies.

Introduction

Fuelwood and timber shortage has become as severe as that of food in many Asian countries. Increasing attention is now being paid to fuelwood and small timber production through agroforestry approach to meet the severe crisis.

Agroforestry is considered one of the most useful tools to alleviate the fuelwood crisis because of its underlying concept of simultaneous production of food and wood (Lundgren & Raintree 1983, Bhumibhamon 1987, Abedin & Quddus 1990). The interest in such systems has greatly increased over the last decades.

In agroforestry systems, multipurpose tree species (MPTS) are thought to be an important component. A large number of multipurpose fast growing tree species have been proposed for agroforestry use, but very little is known about their growth, biomass production and the ecosystems in which they thrive. So, field trials are essential to evaluate and select the suitable MPTS for productive agroforestry systems.

In MPTS trials, much more emphasis has been given to *Leucaena leucocephala* relative to other potential species. There is an urgent need to explore the other tree legumes. *Acacia auriculiformis, Acacia mangium* and *Gliricidia sepium* are becoming popular because of their fast growth, versatile uses, and nitrogen-fixing ability. They need to be evaluated to explore their potentialities.

In tree-crop associations, shading is the most important factor that causes poor performance of understorey crops. Kang *et al.* (1985) recommended severe tree pruning to avoid shading the understorey crops and to expose them to 90% of incident light. They emphasised the positive effect of pruning on the annual crops, but not the negative effects on the tree biomass.

To make the agroforestry approach more realistic and acceptable to farmers, cultivation of arable crops traditionally grown on that site should be continued under the new system. Rice followed by mungbean is a major cropping system used in south and southeast Asia. It is, therefore, an urgent challenge to agricultural scientists working on upland rice-mungbean based agroforestry systems using potential tree legumes.

This present investigation was conducted to evaluate the growth performances of three promising multipurpose tree species (*Acacia mangium, A. auriculiformis* and *Gliricidia sepium*) in close association with annual crops under pruned and unpruned conditions with the view to determine the most suitable species for fuelwood and small timber production in a small-scale agroforestry system.

Materials and methods

The experiment was conducted at the Central Luzon State University College of Agriculture Experiment Farm, Munoz, Nueva Ecija, Philippines for a 24-month period starting from July 1990 to August 1992. The experimental site was of a well-drained, flat, mixed isohyperthermic Udic Haplustalf of clay loam texture located at 15° 43' N, 120° 54' E, and 73 m above mean sea level. The climate is tropical, with an average rainfall of 1950 mm, and is characterised by a distinct rainy season from June to October and a strong dry season from November to May.

About four-month-old seedlings of three multipurpose tree species, raised from seeds were planted at a 3 × 2 m spacing in monoculture treatments, and as intercrops with an annual crop sequence of upland rice (*Oryza sativa*) followed by mungbean (*Vigna radiata*). Each of the intercrops had two alternative tree treatments, either pruned or unpruned. The last treatment was the monocrop of annual crop system. The experiment was laid out in a factorial randomised block design with three replications. The unit plot size was 12 × 12 m. Each plot had five rows of trees, each row contained seven trees.

Tree side branch pruning was done by cutting all side shoots from the base to the tip of the trees, leaving 4-5 small branches at the tip. Uniform pruning was done in all pruned treatment plots irrespective of tree species. The first pruning of trees was done at 10 months, or 3 weeks before seeding of rice. The second pruning was done 70 days after the first pruning (i.e. at the peak rainy season) during the booting stage of rice. The third pruning was done 135 days after the first pruning (i.e. at the later part of the rainy season) or one day before sowing of mungbean. The pruned materials were separated into leaves and branches, and the dry weights were determined. The pruned leaves were applied as mulch.

Upland rice (*Oryza sativa*) was sown in between tree rows 25 cm apart at the onset of rains. Mungbean (*Vigna radiata*) was seeded in furrows after harvest of rice and a day after the third (last) pruning.

Tree height and diameter were measured in all trees every four months and averaged. Tree diameter was measured at 30, 60, 90 and 130 cm (breast height) from the ground. At each sampling date, two trees from each plot were felled to estimate the biomass of tree components at different ages. Litterfall was recorded using litter trap measuring 2 × 2 m with nylon fabric (2-mm mesh). Total above-ground dry biomass was calculated by aggregating the stem, branch, and leaf dry weights of individual trees and the dry weight of litterfall during the four-month period. In the case of pruned treatments, weights of pruned leaf and branch were added. All trees were felled at the end of the study (after two years) to measure the biomass of tree components and the mean total biomass. All data were analysed using IRRISTAT Version 92-1 (1992) microcomputer program. The figures were drawn using Harvard Graphics Version 2.3 and 3.0.

Results and discussion

Height growth

The rate of tree height growth differed significantly among the three species over the period of observation. The presence of associated understorey annual crops did not have a significant effect on the tree height, but tree pruning had a significant effect only in the *A. mangium* species at two years after planting. The growth of the three tree species is shown in Figure 1. During early growth (4 and 8 months after planting), *A. auriculiformis* and *A. mangium* were significantly taller than *G. sepium.* But at one year, *G. sepium* was just as tall as the other two species. The period of dramatic height growth in *G. sepium* coincided with the onset of the rainy season.

At 16 months after planting (MAP), *A. mangium* significantly surpassed the other two species, and *G. sepium* again fell back on its slower growth relative to the other species. The reason for the slower growth in *G. sepium* may be explained by the sudden cessation of the rainy season. Intercropping of rice and mungbean did not have any significant effect on the height growth of any of the tree species. The lack of any effect of intercropping rice and mungbean on the tree height has also been previously reported by ICRAF (1991) and Seibert and Kuncoro (1987).

Acacia mangium maintained its superiority at the end of the study and attained a mean height of 7.60 m. The tendency for superior growth in *A. mangium* has been reported by Latif *et al.* (1985), Boontawee and Kuwalairat (1987), and ICRAF (1991). The height of *A. mangium* was relatively more affected by tree branch pruning. At 24 MAP, a significantly reduced height (7.06 m) was recorded in *A. mangium* in the pruned treatment which was close to that of *A. auriculiformis.*

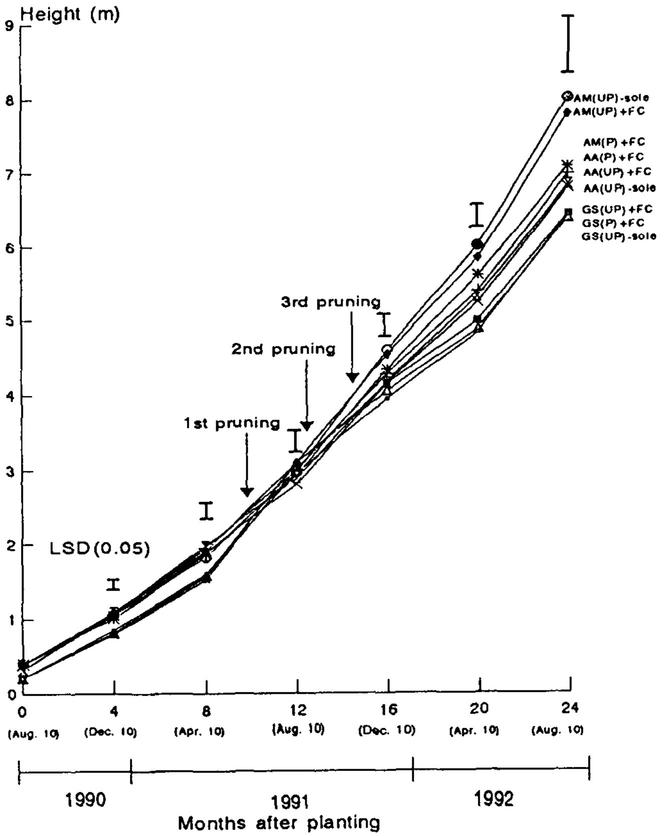

Figure 1. Height of the three multipurpose tree species as affected by pruning and associated field crops [GS = *Gliricidia sepium*; AA = *Acacia auriculiformis*; AM = *Acacia mangium*; P = pruned; UP = unpruned; and FC = field crops (10 - 16 months)]

Annual increment in tree height

The mean annual increment (MAI) in tree height of the three species in the first year (0-12 months) showed that the rate of increase was higher in *G. sepium* (2.84 m) compared to the other two species. The MAI in the other two species were almost the same (Table 1). The MAI in the second year showed that rate of increase was faster in *A. mangium* (4.61 m), followed by *A. auriculiformis* (3.98 m) and *G. sepium* (3.39 m).

Diameter growth

The diameter growth at 30 cm above ground level height varied significantly among the species at all dates of measurement. Diameter growth remained unaffected by the associated field crops. Tree pruning had a significant effect on the *A. mangium* species only (Figure 2).

Table 1. Mean annual increment (MAI) in height growth of the three multipurpose tree species as influenced by pruning treatment

Tree species and pruning treatment	MAI in height growth (m y^{1}) Age (months) 0-12	MAI in height growth (m y^{1}) Age (months) 12-24
G. sepium		
Pruned+FC	2.90	3.47
Unpruned+FC	2.77	3.42
Sole tree	2.84	3.29
Mean	2.84	3.39
A. auriculiformis		
Pruned+FC	2.67	3.97
Unpruned+FC	2.48	4.04
Sole tree	2.88	3.94
Mean	2.57	3.98
A. mangium		
Pruned+FC	2.52	4.14
Unpruned+FC	2.69	4.67
Sole tree	2.56	5.02
Mean	2.59	4.61

At 4 MAP, diameter growth among the three species was almost similar. At 8 MAP, *A. auriculiformis* outgrew the other two species. After 8 months, diameter growth in *A. mangium* became faster than that in *A. auriculiformis* and *G. sepium* and continued thus thereafter. After one year, a wide variation in diameter growth was noted: the faster growth was seen in *A. mangium,* it was intermediate in *A. auriculiformis,* and slower in *G. sepium.* At 16 MAP, the diameter of *A. mangium* was 6.03 cm. Beginning at 16 MAP, *A. mangium* pruned trees had significantly smaller diameter than unpruned trees.

Unpruned *A. mangium* maintained a significantly higher diameter growth (12.1 cm) as compared to the other two species at 24 months of age. Superior performance by *A. mangium,* compared to *Acacia auriculiformis* and other species has also been reported by Huang and Zheng (1989), and Halenda (1988). *Acacia auriculiformis* was second in diameter growth and superior to *G. sepium* in this study. Figure 2 also demonstrates that over the period, slower rate of diameter growth was more pronounced in *G. sepium* during the dry season relative to the other species. In *G. sepium,* the slower growth rate started at the early part of the dry season (November). In *A. auriculiformis,* the slower rate started at the middle part of the dry season (January). In contrast, *A. mangium* was affected to a lesser degree.

The diameter growth at 60 cm , 90 cm and breast height (130 cm) showed a trend almost similar to that at 30 cm height with few exceptions at the early stages (up to 12 MAP). But, the diameter growth trend indicated that diameter growth of *A. auriculiformis* at greater height levels decreased relatively faster than in the other two species.

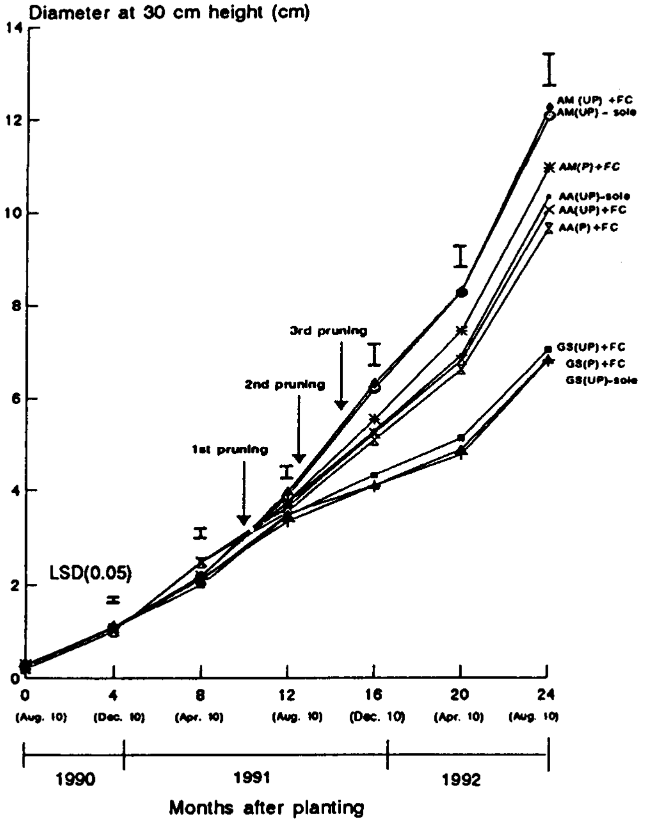

Figure 2. Diameter at 30 cm height of the three multipurpose tree species as affected by pruning and associated field crops [GS = *Gliricidia sepium*; AA = *Acacia auriculiformis*; AM = *Acacia mangium*; P = pruned; UP = unpruned; and FC = field crops (10-16 months)].

Annual increment in tree diameter

The mean annual increment (MAI) in diameter growth showed that differences in yearly increment among the species were not much in the first year (Table 2). But in the second year, the MAI in diameter growth in *A. mangium* (7.87 cm) was 2.3 times faster than that in *G. sepium* (3.46 cm). *Gliricidia sepium* recorded a slower diameter increase in the dry period than in the wet period relative to the other species.

Biomass of tree components

Leaf dry biomass

Differences in leaf dry biomass among the three tree species varied significantly at all sampling dates. *Acacia auriculiformis* produced the highest leaf biomass at all dates of sampling, followed by *A. mangium* and then *G. sepium*. Leaf dry biomass, irrespective of species, was affected by pruning but not by the presence of associated annual crops (Figure 3).

Table 2. Mean annual increment (MAI) in diameter growth (at 30 cm height) of the three multipurpose tree species as influenced by pruning treatment

Tree species and pruning treatment	MAI in height growth (m y^{1}) Age (months) 0-12	 12-24
G. sepium		
Pruned+FC	3.11	3.46
Unpruned+FC	3.22	3.57
Sole tree	3.24	3.35
Mean	3.19	3.46
A. auriculiformis		
Pruned+FC	3.34	6.11
Unpruned+FC	3.44	6.41
Sole tree	3.52	6.60
Mean	3.43	6.37
A. mangium		
Pruned+FC	3.46	7.17
Unpruned+FC	3.66	8.26
Sole tree	3.57	8.18
Mean	3.56	7.87

Leaf dry biomass recorded after the first pruning (12 MAP) showed that *A. auriculiformis* and *A. mangium* pruned trees produced significantly lower yields than the unpruned trees, while leaf dry biomass of *G. sepium* pruned trees was statistically similar to that of the unpruned. After the second and third pruning (16 MAP), differences in leaf dry biomass between pruned and unpruned trees in *A. auriculiformis* and *A. mangium* species became wider. But the differences in *G. sepium* were still insignificant, indicating that *G. sepium* has better coppicing ability when pruned. Superior coppicing ability in *G. sepium* has also been reported by several investigators (Yamoah *et al.* 1986, Kang & Mulongoy 1987, Atta-Krah & Sumberg 1987, Bandara & Gunasina 1989).

At 20 MAP, *G. sepium* pruned trees exhibited lower leaf dry biomass than the unpruned trees like the other two species. This was probably due to the effect of the drier season, i.e. less coppicing ability at that time.

After 20 months, the rate of increase in leaf dry biomass, irrespective of species and pruning accelerated, while differences in leaf dry biomass between pruned and unpruned trees became wider. At the end of two years, highest leaf biomass was shown by *A. auriculiformis* (unpruned) trees, followed by *A. mangium* (unpruned), *A. auriculiformis* (pruned), *A. mangium* (pruned), *G. sepium* (unpruned), and *G. sepium* (pruned). Two years after planting, the pruned trees had 33-35% lower leaf dry biomass than the unpruned trees. Regardless of pruning, the highest total leaf dry biomass was exhibited by *A. auriculiformis* (10 930 kg ha^{-1} in mean value among the treatments, 12 465 kg ha^{-1} for the unpruned treatments).

This was followed in mean value among the treatments by *A. mangium* (9046 kg ha^{-1}) and *G. sepium* (4952 kg ha^{-1}). The lesser leaf biomass in *G. sepium* among the tree species has also been reported by Kang *et al.* (1981). The differences in leaf dry biomass among species may be attributed to differences in the inherent potentiality of the species.

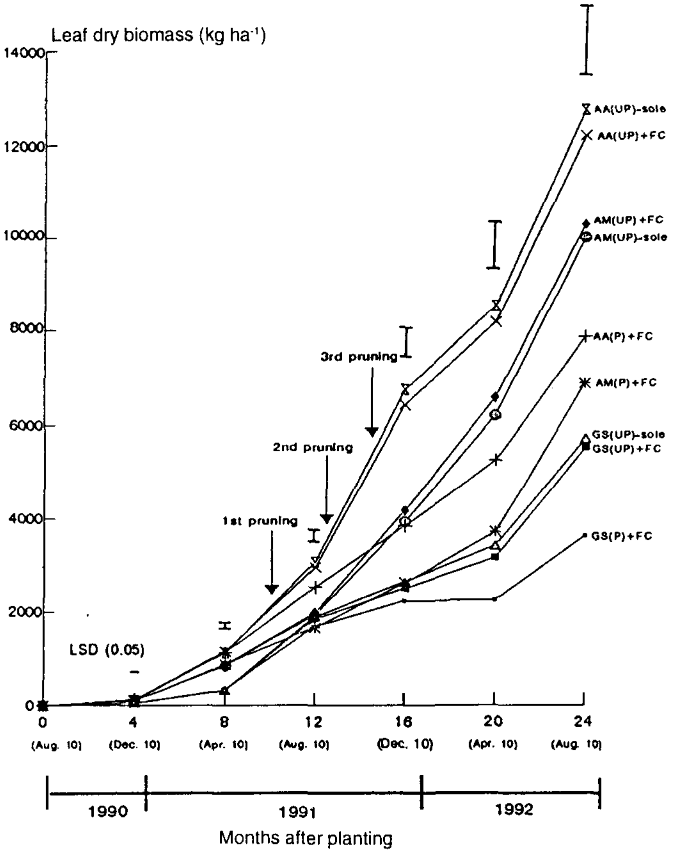

Figure 3. Leaf dry biomass of the three multipurpose tree species as affected by pruning and associated field crops [GS = *Gliricidia sepium*; AA = *Acacia auriculiformis*; AM = *Acacia mangium*; P = pruned; UP = unpruned; and FC = field crops (10-16 months)]

Branch dry biomass

Branch dry biomass of the three tree species recorded at 4-month intervals showed significant variation among the species in all observations periods. Pruning treatments severely affected branch dry biomass of the three MPTS but not growing of the associated field crops (Figure 4). At 12 MAP, when first pruning was done, significantly lower branch dry biomass was observed in pruned trees, irrespective of species. At 16 MAP, when all three prunings were done, differences between pruned and unpruned trees became wider — unpruned trees had almost double the branch dry biomass, irrespective of species.

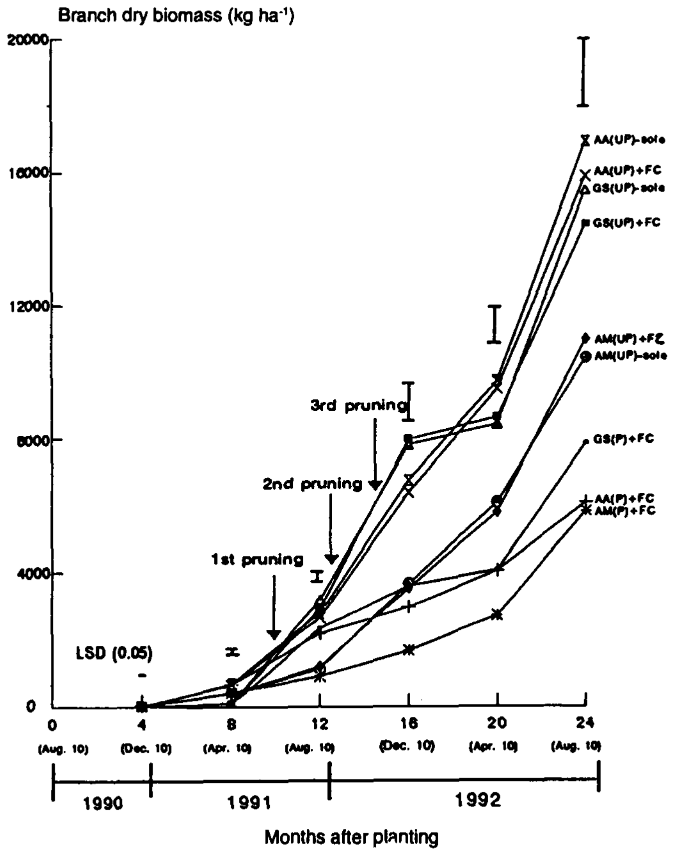

Figure 4. Branch dry biomass of the three multipurpose tree species as affected by pruning and associated field crops [GS = *Gliricidia sepium*; AA = *Acacia auriculiformis*; AM = *Acacia mangium*; P = pruned; UP = unpruned; and FC = field crops (10-16 months)]

At 20 and 24 MAP, an almost similar trend of variation between pruned and unpruned trees was observed but differences in *A. auriculiformis* became even wider. At 2 years, pruned trees produced 49, 62 and 47% lower branch dry biomass in *G. sepium*, *A. auriculiformis*, and *A. mangium* respectively.

Among the species, a wide variation in branch dry biomass was observed after 8 MAP until the end of the study (24 MAP). At this time, *A. auriculiformis* (unpruned, sole) trees produced the highest branch dry biomass (16 881 kg ha^{-1}; 16 368 kg ha^{-1} mean value for unpruned trees), closely followed by *G. sepium* (15 439 kg ha^{-1}); *A. mangium* produced the lowest branch dry biomass (10 401 kg ha^{-1}). These variations indicate the heavy branching habit of *A. auriculiformis* and *G. sepium* species. Heavy branching in *A. auriculiformis* (Pinyopusarerk 1990) and a good straight bole with minimal branching in *A. mangium* (Yantasath 1987) have been previously reported.

Stem dry biomass

The differences in stem dry biomass of the three species were not remarkable until they were 12 months of age. At 16 months, the unpruned stem dry matter of *A. mangium* was significantly higher (6517 kg ha^{-1}) than that of *G. sepium* (5562 kg ha^{-1}) and *A. auriculiformis* (5062 kg ha^{-1}). Thereafter, *A. mangium* remained as the highest stem dry matter yielder (Figure 5). *Acacia auriculiformis* surpassed *G. sepium* during the dry season (20 MAP), but their difference became less during the following wet season (24 MAP).

Following two years of evaluation, the highest yield was obtained by *A. mangium* (17141 kg ha^{-1}), followed by *A. auriculiformis* (14 307 kg ha^{-1}) and *G. sepium* (13 792 kg ha^{-1}).

The effects of pruning were not visible at the early part of the treatment, but they were apparent at 20 and 24 MAP in *A. mangium* and at 24 MAP in *G. sepium* only. Stem dry matter of *A. auriculiformis* remained unaffected. However, the production of the intercrops did not affect any of the species.

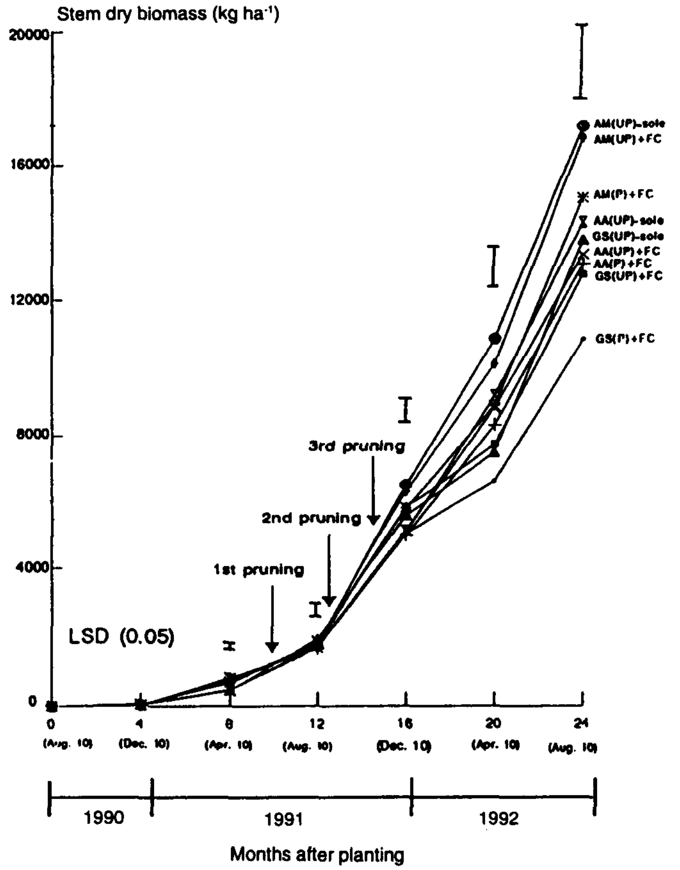

Figure 5. Stem dry biomass of the three multipurpose tree species as affected by pruning and associated field crops [GS = *Gliricidia sepium* ; AA = *Acacia auriculiformis*; AM = *Acacia mangium*; P = pruned; UP = unpruned; and FC = field crops (10-16 months)]

Total above-ground biomass

Total above-ground biomass production by species varied significantly throughout the harvesting periods. *Acacia auriculiformis* produced the highest total biomass at all ages observed (Figure 6). The higher biomass productivity of *A. auriculiformis* could be attributed to higher leaf and branch biomass production. Higher above-ground biomass production of *A. auriculiformis* has also been observed by Petmak (1983) who compared it with three other MPTS. Between *A. mangium* and *G. sepium*, *G. sepium* produced higher biomass than *A. mangium* at 8 months; this trend continued until 16 months, after which *A. mangium* surpassed *G. sepium*. This lower productivity of *G. sepium* might be caused by the severe dry season. Exactly similar production trends were noticed in the stem and branch components of *G. sepium* during the same period of growth.

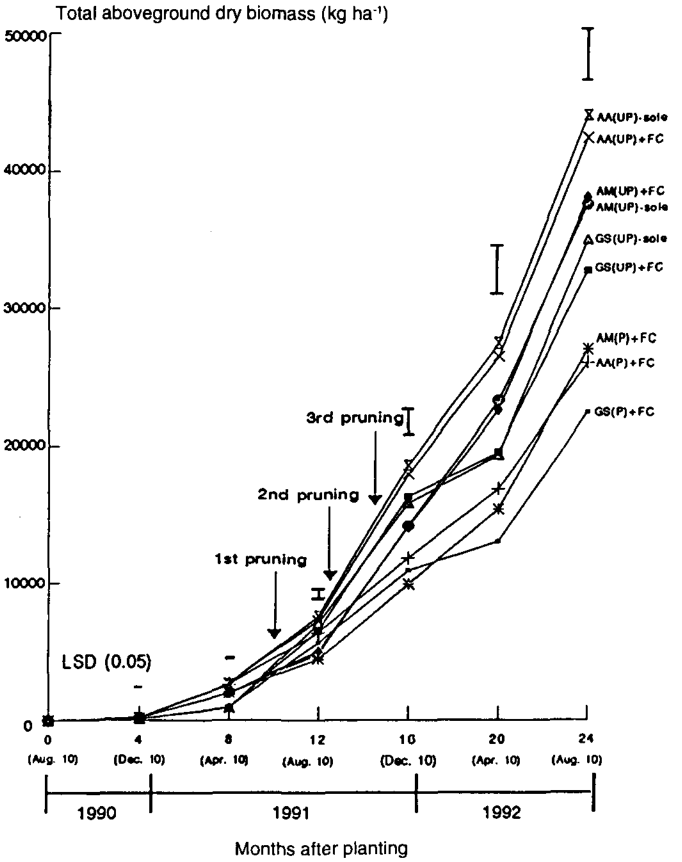

Figure 6. Total above-ground dry biomass of the three multipurpose tree species as affected by pruning and associated field crops [GS = *Gliricidia sepium*; AA = *Acacia auriculiformis*; AM = *Acacia mangium*; P = pruned; UP = unpruned; and FC = field crops (10-16 months)]

At two years, the highest mean total above-ground dry biomass values produced by the tree species were as follows: 43 935 kg ha^{-1} for *A. auriculiformis,* 37 523 kg ha^{-1} for *A. mangium,* and 34 940 kg ha^{-1} for *G. sepium.*

The effects of pruning on above-ground biomass were highly significant while the effects of growing intercrops were not. Pruned treatments produced lower biomass than the unpruned beginning with the first pruning. The magnitude of the difference increased as the trees grew older. At two years, the biomass of the pruned trees was 31.7% lower in *G. sepium,* 38.5 % lower in *A. auriculiformis,* and 27% lower in *A. mangium.*

Biomass distribution pattern

The biomass distribution pattern of various components of the three MPTS to the total above-ground biomass production showed that leaf, branch and stem respectively contributed 16.5, 41.1 and 42.4% in *G. sepium;* 29.0, 32.8 and 38.2% in *A. auriculiformis;* 26.1, 25.9 and 48.0% in *A. mangium* (Table 3). The results indicate that in *G. sepium,* branch and stem contributed 83.5% of the total biomass; in *A. auriculiformis,* the contributions of the three components were almost equal; in *A. mangium,* the stem alone contributed about half of the biomass (48.0%). These differences might be due to the species differences rather than pruning treatments.

Table 3. Component-wise biomass distribution (%) in the 2-y-old three multipurpose tree species as influenced by pruning treatment

Tree species and pruning treatment	Biomass distribution (%)		
	Leaf	Branch	Stem
G. sepium			
Pruned + FC	16.2	35.2	48.6
Unpruned + FC	17.0	44.0	39.0
Sole tree	16.3	44.2	39.5
Mean	16.5	41.1	42.4
A. auriculiformis			
Pruned + FC	29.1	24.6	46.3
Unpruned + FC	28.8	35.5	35.7
Sole tree	29.0	38.4	32.6
Mean	29.0	32.8	38.2
A. mangium			
Pruned + FC	24.8	21.1	54.1
Unpruned + FC	27.0	28.8	44.2
Sole tree	26.6	27.7	45.7
Mean	26.1	25.9	48.0

Effect of tree-crop association on the growth and yield of annual crops

Crop growth, yield and yield components of upland rice and mungbean were significantly better in the pruned plots compared to the unpruned plots. The yields of upland rice and mungbean in the pruned plots were similar to those in the sole plots, considering the ground area actually occupied by the annual crops. The better performance of rice and mungbean in the pruned plots could be due to benefits obtained from severe tree pruning and use of pruned leaves as green manure and mulch. Compared with the pruned plots, the mean yield reductions of rice and mungbean in the unpruned plots were 61 and 78% respectively. The drastically lower yields in the unpruned plots could be attributed to the combined effects of severe shading and competition for below-ground resources.

Conclusion

The results of the present study revealed that tree pruning had a marked negative effect in tree growth and biomass, but had a significantly positive effect on the growth and yield of annual crops. Although a substantial amount of tree biomass was sacrificed because of pruning, about 25 t of dry biomass ha^{-1} from pruned trees in two years would be very lucrative for farmers who can use it as fuel. The results clearly indicate that where growing annual crops is the main objective, trees must be pruned, particularly during the crop-growing season. However, sustainability of this approach is difficult to assess over a short period of time. A long-term study should be done to determine the sustainability and profitability of such a system.

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