Effect of plant density and cutting frequency on the yield of four tree legumes and interplanted *Panicum maximum* cv. Riversdale

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Abstract

In a tropical environment with a distinct dry season the tropical tree legumes *Calliandra calothyrsus, Sesbania grandiflora, Leucaena leucocephala* and *Gliricidia sepium* were planted at a density of 5000, 10000, 20000 and 40000 trees/ha and cut at intervals of either 6 or 12 weeks. An understorey grass, *Panicum maximum* cv. Riversdale, was established and this grass was harvested at the same time as the respective tree legume treatment.

Less than 50% of *Sesbania grandiflora* trees survived the regular cutting in this experiment while almost all trees of the other species survived. Tree leaf yields of the three surviving species were positively related to tree density in the wet season but less so in the dry season. The longer cutting interval produced a higher leaf yield in the first wet season harvest but not in later harvests when rainfall was lower.

In the wet season, the shorter cutting interval tended to produce higher grass yields in the higher densities while no differences between cutting intervals occurred in the lower tree densities. On the contrary, in the dry season grass yields were higher overall in the longer cutting interval and the higher tree densities.

Resumen

Las leguminosas arbóreas Calliandra calothyrsus, Sesbania grandiflora, Leucaena leucocephala *y* Gliricidia sepium *fueron plantadas a las densidades de 5000, 10000, 20000 y 40000 árboles/ha, en un medio ambiente tropical con una estación seca distintiva, y fueron cortadas a intervalos de 6 o 12 semanas. La gramínea* Panicum maximum *cv. Riversdale fue establecida abajo de los árboles y fue cosechada al mismo tiempo que el respectivo tratamiento de leguminosa arbórea.*

Menos del 50% de los árboles de Sesbania grandiflora *sobrevivieron al corte regular en este experimento, mientras que casi todos los árboles de las otras especies sobrevivieron. El rendimiento de hoja de tres de las especies arbóreas que sobrevivieron estuvo positivamente relacionado con la densidad de árboles en la estación lluviosa pero esta relación fue menor en la estación seca. Los intervalos de corte largos produjeron un mayor rendimiento de hoja en la primera cosecha de la estación lluviosa pero no así en las cosechas posteriores cuando la lluvia fue menor.*

En la estación húmeda, los intervalos de defoliación cortos produjeron mayores rendimientos de la gramínea en las altas densidades mientras que no se encontró diferencias entre los intervalos de defoliación en las bajas densidades de árboles. Por el contrario, el rendimiento de la gramínea durante la estación seca fue globalmente superior en los intervalos de corte largos y en las altas densidades de árboles.

Introduction

In an earlier paper, Ella *et al.* (1989) reported that leaf and wood yields of *Leucaena leucocephala* cv. Cunningham, *Calliandra calothyrsus, Gliricidia sepium* and *Sesbania grandiflora* were positively related to tree density in the wet but not, or to a lesser extent, in the dry season in South Sulawesi, Indonesia. In their study, leaf and wood yields were higher in the 6-weekly than 12-weekly cutting interval in the wet season in all species except *S. grandiflora*.

Working in the same environment, Catchpoole and Blair (1990) recorded higher edible dry matter

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production from a combination of tree legumes (*Leucaena leucocephala, Calliandra calothyrsus* and *Gliricidia sepium* planted at 10000 trees/ha) and understorey *Panicum maximum* than from tree or grass monocultures alone. In a review of pastures in plantations Shelton *et al.* (1987) suggested that understorey pastures may have both positive and negative effects on the plantation crop.

The present experiment was conducted to examine the effect of tree density and cutting frequency on leaf yield of tree and yield of underplanted grass.

Materials and methods

Treatments and design

The experiment was conducted at the Balai Penelitian Ternak Research Station at Gowa, South Sulawesi. The first phase of the experiment when only trees were present has been published previously (Ella *et al.* 1989).

The experiment was designed as a split/split plot with two cutting frequencies (6 and 12 weeks between defoliation) as the main plots and four tree densities (5000, 10000, 20000 and 40000 trees/ha) as sub-plots. The tree species *Sesbania grandiflora* (local), *Calliandra calothyrsus* (local), *Gliricidia sepium* (local) and *Leucaena leucocephala* cv. Cunningham were planted as sub/sub-plots. All treatments were replicated three times and replicates were arranged as blocks.

Establishment

The alluvial soil of the site was low in sulfur and, to a lesser extent, phosphorus. The trees were planted in February 1984 and a basal application of 100 kg/ha elemental sulfur, 100 kg/ha triple superphosphate and 60 kg/ha muriate of potash were broadcast after planting. After an establishment phase of one year, all trees were cut to a height of 100 cm on February 14 and April 22, 1985 to promote a uniform stand. For the following year, trees were cut at 6- or 12-weekly intervals and leaf and wood yields of this tree-only phase have been published in Ella *et al.* (1989). Seed of *Panicum maximum* cv. Riversdale was undersown on January 18, 1986. During the grass establishment period trees were cut back to 100 cm at 6- or 12-weekly intervals. On April 16, 1986, when the grass was well and evenly established, the grass was cut back to 12 cm and the trees were cut back to 100 cm. This was deemed the beginning of the experiment reported here.

Measurements

Trees were harvested every 6 or 12 weeks at a height of 100 cm. The interplanted grass was cut to a height of 12 cm at the same time as the trees. Trees and grass in the central area of the plot were harvested, and tree leaf and grass yields were measured after drying samples at 70 °C to a constant weight.

Results

Rainfall amounted to 1120 mm during the establishment phase (January 18 - April 16, 1986) and 360, 170 and 690 mm in the 3-month period leading to Harvests 1, 2 and 3 respectively.

Tree survival

Neither in the tree only (Ella *et al.* 1989) nor in the tree plus grass phase, did tree density have an effect on the survival of any of the four tree species. Cutting frequency also had no effect on the survival of *L. leucocephala* or *G. sepium* and only a small effect on *C. calothyrsus.*

On the other hand, *S. grandiflora* survival appeared to be severely affected by cutting. Trees began to die in the previously reported trees only phase (Ella *et al.* 1989). At the beginning of the tree plus grass phase 70% of trees were still alive and this declined to 42% and 33% of the original *S. grandiflora* trees in the 6- and 12-weekly cutting treatments, respectively, by the end of the experiment.

Tree leaf production

The effects of density and cutting frequency in this phase of the experiment were similar to those in the earlier tree only phase (Figure 1; harvests refer to the 12-weekly cutting interval and consecutive pairs of 6-weekly cutting harvests). Briefly, tree leaf yields were positively related to density in the wet season (Harvests 1 and 3, Figure 1) but less so in the dry season (Harvest 2, Figure 1). Only in Harvest 1 was there a significant ($P < 0.05$) difference between leaf yields in the 6- and 12-weekly cutting interval in *C. calothyrsus, L. leucocephala* and *G. sepium*, with higher yields recorded in the longer interval (Figure 1).

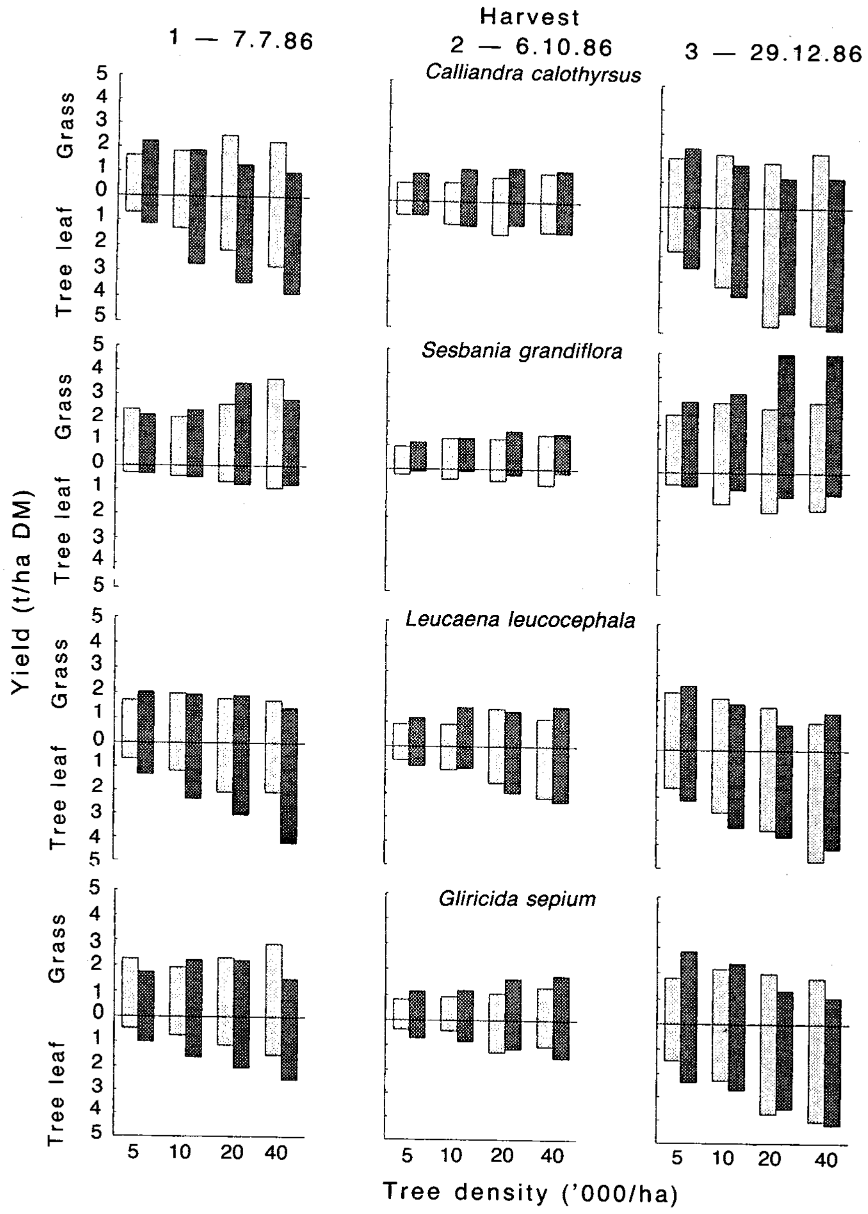

Figure 1. Grass and tree leaf yields (DM t/ha) in the 6-□ and 12-weekly ■ cutting frequency treatments under four tree legumes grown at different plant densities (harvests refer to the 12-weekly cutting interval and consecutive pairs of 6-weekly cutting harvests).

Grass production

A significant ($P<0.05$) three-factor interaction between companion species, cutting frequency and tree density was obtained for grass yields in Harvests 1 and 3, while no interaction occurred in Harvest 2.

Grass yields were significantly higher ($P<0.05$) under *S. grandiflora* than under any other tree legume at Harvests 1 and 3 (Figure 1). In Harvest

2, which was taken in the dry season, there were no significant differences (P<0.05) between species in grass production. Grass yields under *C. calothyrsus*, *L. leucocephala* and *G. sepium* were not significantly (P<0.05) different in Harvest 3.

At Harvest 1 there was a significantly higher (P<0.05) grass yield in the 6- than in the 12-weekly cutting interval at the highest tree density of *G. sepium* and at the two highest densities of *C. calothyrsus*. At Harvest 2 (Figure 1), when rainfall was lower, there was a higher grass yield (main effect P<0.05) in the 12- than in the 6-weekly cutting interval. At Harvest 3, grass yield was higher (P<0.05) in the 6- than in the 12-weekly cutting interval under *C. calothyrsus* at the highest density. On the contrary, grass yield under the lowest density of *G. sepium* and the two highest densities of *S. grandiflora* were higher in the 12- than in the 6-weekly cutting interval.

When comparing grass yields under different plant densities at Harvest 1, there were no differences in either cutting frequency under *L. leucocephala*. Under *C. calothyrsus* differences only occurred in the 12-weekly cutting interval treatment, where grass yields were lower in the higher densities than in the lower densities. Under *S. grandiflora*, grass yield tended to be higher in the denser plantings, but this result is confounded with tree death. Although grass yield under *G. sepium* was lower in the 40000 trees/ha planting of the 12-weekly cutting interval than at lower plant densities, this difference was statistically not significant (P<0.05). At Harvest 2 grass yields were positively related to tree density (P<0.05). At Harvest 3 grass yields under *C. calothyrsus*, *L. leucocephala*, and *G. sepium* were higher in the lower than in the higher densities in the 12-weekly cutting frequency treatments, and this also occurred in the 6-weekly cutting frequency

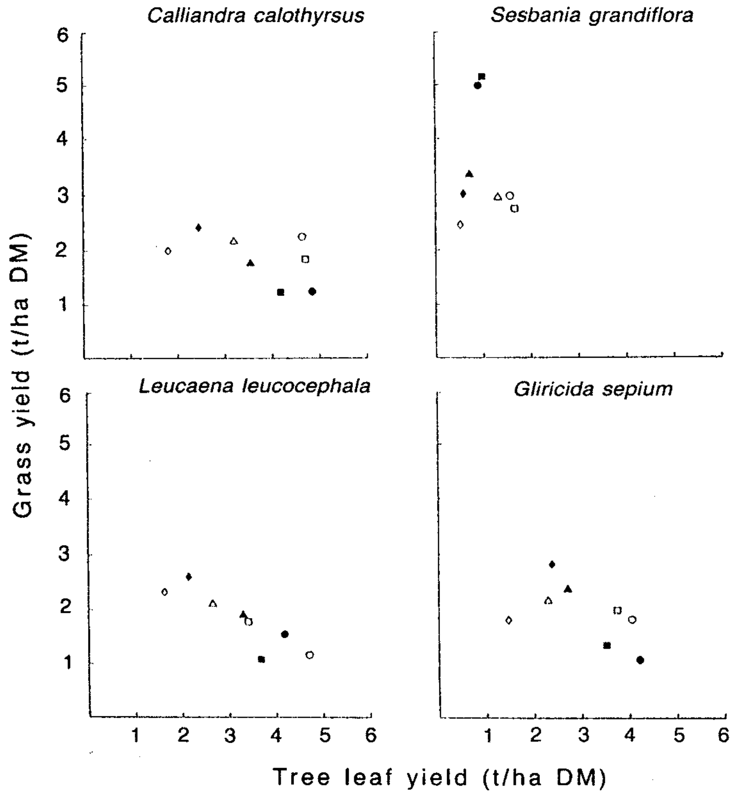

Figure 2. Relation between understorey grass and tree leaf yield of four tree legumes grown at 5000 (◆), 10000 (▲), 20000 (■) and 40000 (●) trees/ha and cut every 6 (open symbols) or 12 (filled symbols) weeks at Harvest 3.

under *L. leucocephala*. There were no differences in grass yield between densities in the 6-weekly cutting frequency treatments of *C. calothyrsus*, *G. sepium* and *S. grandiflora*. In the 12-weekly cutting frequency treatment of *S. grandiflora*, grass yields were higher under the two higher tree densities.

The relation between grass and tree leaf yields varied with tree species, tree density and cutting frequency (Figure 2; Harvest 3). No clear relation was apparent in *S. grandiflora* where tree deaths occurred. The relation between grass yield and leaf yield was strongly negative at the 12-weekly cutting frequency for *C. calothyrsus*, *L. leucocephala* and *G. sepium* but only for *L. leucocephala* at the 6-weekly cutting frequency. Similar relations also existed in Harvest 1 but not in the dry season in Harvest 2.

Discussion

The total dry matter production of the understorey grass was highest when grown with *S. grandiflora* (11.1 t/ha/yr), and there was little difference between *G. sepium, L. leucocephala* and *C. calothyrsus* (7.8, 7.4 and 7.2 t/ha/yr respectively). The higher grass yield under *S. grandiflora* was probably the result of a higher amount of radiation reaching the grass, since many *S. grandiflora* trees died and had a much lower yield than the other tree legumes. The three higher yielding tree species shaded the grass to a greater extent.

In grass-legume associations, competition for light between the species is often the most important factor influencing yield and survival (Santhirasegaram *et al.* 1966). Yield of many grasses and legumes has been reported to decline when shading is imposed (Burton *et al.* 1959; Ludlow 1978). Species vary, however, in their relative tolerance to reduced light intensity. *Panicum maximum* had a higher production than *Digitaria eriantha* (pangola grass), *Pennisetum clandestinum* and *P. purpureum* when grown under a low light intensity (Eriksen and Whitney 1982), and was ranked as being moderately shade-tolerant when grown under coconut trees (Shelton *et al.* 1987; Reynolds 1978).

In the dry season there was no difference in yield of grass grown under *S. grandiflora* and the other three tree legumes, despite significant differences in tree yield and it is suspected that water, rather than light, was the most limiting factor for grass growth during this period. Grass yields were generally high under all tree species and large differences between tree densities occurred only with the longer cutting frequency. In the wet season harvests the shorter cutting interval tended to produce higher grass yields in the higher tree densities while only small differences between cutting interval occurred in the lower tree densities. On the contrary, in the dry season (Harvest 2) grass yields were higher overall in the longer cutting interval and the higher tree densities. A higher herbage production under trees when compared with open grassland during drought years has also been observed in California (Frost and McDougald 1989). Grass growth in the wet season may be explained by a lower light intensity reaching the lower-growing grass in the higher tree densities and longer cutting intervals, while it is suspected that the same treatments provided some shade and protection for grasses in the dry season when water was probably the most limiting factor. Reduced direct sunlight may have resulted in a reduced transpiration and evaporation rate in these more heavily shaded treatments. These results suggest that the grasses and trees obtained moisture from different levels in the profile. This is supported by the results of other experiments conducted at the same location (Catchpoole and Blair 1990). The experiment confirms that the planting of a shade-tolerant grass like *Panicum maximum* makes a net contribution to overall forage supply and, in addition, may provide a more balanced protein/roughage feed supply and enhance erosion control.

Acknowledgements

We thank the Balai Penelitian Ternak and the AIDAB-funded Forage Research Project for facilities and financial assistance, and Dr D. Ivory for advice in setting up the experiment.

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(Received for publication December 20, 1990; accepted June 1, 1991)