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Light availability to the understorey annual crops in an agroforestry system

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Abstract

Light availability was determined in the understorey annual crop rows at different distances from the tree rows of three Multipurpose Tree Species (MPTS) under pruned and unpruned conditions. The MPTS were *Gliricidia sepium*, *Acacia auriculiformis* and *Acacia mangium*; and the annual crops were upland rice and mungbean. Rice was row-seeded in alleys between 10-month-old trees, and mungbean was seeded in furrows immediately after harvest of rice. The trees, which were planted in a 2m x 3m geometry, were pruned three times during the year. The mean reduction of light incidence on rice and mungbean rows was minimal in the pruned alleys (3-10%), but it was severe in the unpruned alleys (53-59%). Across the alleys, mean light availability on crop rows decreased as they approached the tree rows. The rate of decrease was greater in unpruned than in pruned alleys; percent incident radiation was highest under *G. sepium*. Rice and mungbean yields decreased linearly with reduced percent light incidence. For every percent decrease in relative light incidence, rice yields decreased 47 kg.ha^{-1} and mungbean yields decreased 10 kg.ha^{-1}. In pruning regimes, mungbean yields decreased more in pruned conditions (13 kg.ha^{-1}) than in unpruned conditions (9 kg.ha^{-1}), probably because of a less favourable canopy microclimate under drought stress.

Introduction

Agroforestry (alley cropping) has emerged as a sound technology where tree leaves are periodically pruned to prevent shading the companion crops (Kang *et. al.*, 1981, 1985). Cut materials are applied as green manure or mulched at planting and/or during the cropped period (Miah, 1993), because legume tree-based agroforestry normally yields sustained outputs as compared with agroforestry with ordinary trees. The primary reason for this yield difference is the nitrogen fertilizer contributed by leguminous trees (Vergara, 1982). Tree legumes have the ability to return nitrogen to the soil through leaf/root decomposition and nitrogen fixation to improve growth of agricultural crops and thereby improve crop productivity (Macklin, 1990) and soil fertility (Young, 1986). This system has focused mainly on growing maize and cowpea while other dominant arable crops have been neglected. Rice followed by mungbean is a major cropping system used in South and Southeast Asia which should get priority in agroforestry research.

Crop yields, whether perennial or annual, depend directly on the amount of radiant energy they intercept (Jackson, 1983). In agroforestry systems, light availability may be the most important limitation to the performance of the understorey annual crops, particularly where an upperstorey perennial forms a continuous overstorey canopy. Under given site conditions, light availability to the understorey crops is dependent on the size of the tree, the species characteristics such as crown shape and density, and tree management practices.

Tree management practices like side-branch pruning may be important techniques to minimize the effect of light stress on the growth, development, and yield of understorey annual crops. The degree of pruning affects the level of light availability to the understorey crops. Though pruning of the lower branches may reduce the light interception by the tree canopy (Neuman and Pietrowicz, 1987), severe pruning may be useful to expose the understorey crops to most of the incident light and to avoid a shading effect (Kang *et al.*, 1985).

To optimize the productivity of systems, it is essential to know the proportion of the total light which will be available to the annual crop(s), and its distribution across the alley. In the present study an attempt was made to quantify the proportion of light availability to the understorey annual crop rows at different distances from the tree rows in an agroforestry system involving three multipurpose tree species (MPTS) under pruned and unpruned conditions.

1. Materials and methods

The work was conducted in a well managed agroforestry field at the Central Luzon State University College of Agriculture farm from August to December 1991. The study site is located at 15°43′ N latitude and 120°54′ E longitude with an elevation of 73 m above sea level. The climate of the area is warm tropical, characterized by a distinct dry season from November to May and a wet season from June to October.

Three MPTS (*Acacia mangium, Acacia auriculiformis* and *Gliricidia sepium*) formed the upper canopy treatments while two annual crops (rice and mungbean) formed the lower canopy. The MPTS were planted at 3 m x 2 m spacing as monocrops as well as intercrops with an annual crop sequence of rice followed by mungbean. Each of the intercrops had two alternative pruning regimes, either pruned or unpruned. The last treatment was the monocrop of the annual crop system. MPTS were planted in East-West and North-South orientations and annual crops were planted along the alleys. It may be mentioned here that no remarkable variations in any studied parameter were noted due to orientations during the study period.

Upland rice (UPLRi-7) was sown in between the 10-month-old tree rows at 100 $kg.ha^{-1}$ in rows 25 cm apart. Mungbean (Pag-asa 7) was sown in furrows after rice harvest, maintaining a 45 cm row spacing.

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. The first pruning of trees was done 3 weeks before, and the second pruning was at 47 days after rice sowing. The final pruning was done a day before sowing mungbean.

Light incidence was measured on crop rows as a function of distance from the tree rows using tube solarimeters (Szcicz *et. al.*, 1964). Recorded light incidence values were expressed in percent considering the sole crop plot values as 100. Two measurements were taken for each crop period: in rice at the panicle initiation and ripening stages; and in mungbean at 30 days after emergence (DAE) and 50 DAE. Light incidence was measured just above the canopy of rice and mungbean crops in agroforestry treatments and in the respective sole crop plots at 08:30-10:00, 11:30-13:00, and 14:30-16:00. Timetable of light measurements, pruning and growth stages of crops is shown in figure 1.

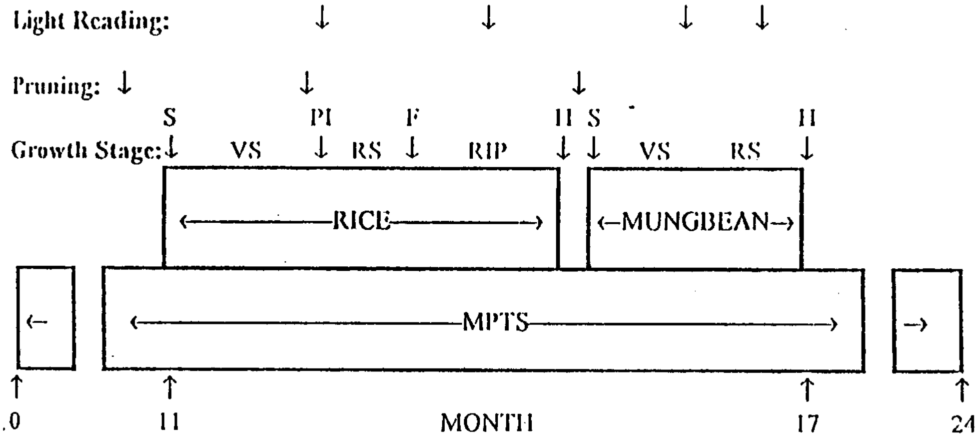

Figure 1. Timetable of light measurements, tree pruning and growth stages of crops: F = Flowering, H = Harvesting, PI = Panicle Initiation, RIS = Ripening Stage, RS = Reproductive Stage, S = Sowing, VS = Vegetative Stage.

Percent light incidence was measured from all 10 rows of rice and 6 rows of mungbean within an alley. Values of two similarly positioned rows relative to the tree rows on opposite sides of the alley were averaged to express the value of a pair of rows. Thus the rows nearest to the tree constituted the 1st pair and the next rows on either side of the alley constituted the 2nd pair, and so on.

2. Results and discussion

2.1 Light availability to the understorey crops

2.1.1 Rice crop

The mean percent light incidence across the alley for three tree species on the understorey rice rows measured at panicle initiation stage (50 DAE i.e., 11 days after the second pruning) and at ripening stage (90 DAE i.e., 51 days after the second pruning) is shown in figure 2. In the pruned alleys the average mean reduction of incident light on the rice rows was minimal while it was severe in the unpruned alleys. The trend in light availability both at the panicle initiation and ripening stages was similar. Overall, light availability values were higher in the first measurement than those taken in the second measurement, due to incremental growth of the overstorey trees. The mean percent light reduction in the full alley in the pruned treatments was 3-7% and 6-10% at the panicle initiation and ripening stages, respectively. In the unpruned treatments, the corresponding values were 53-57% and 54-59%. Among the MPTS, light transmission ability did not vary much.

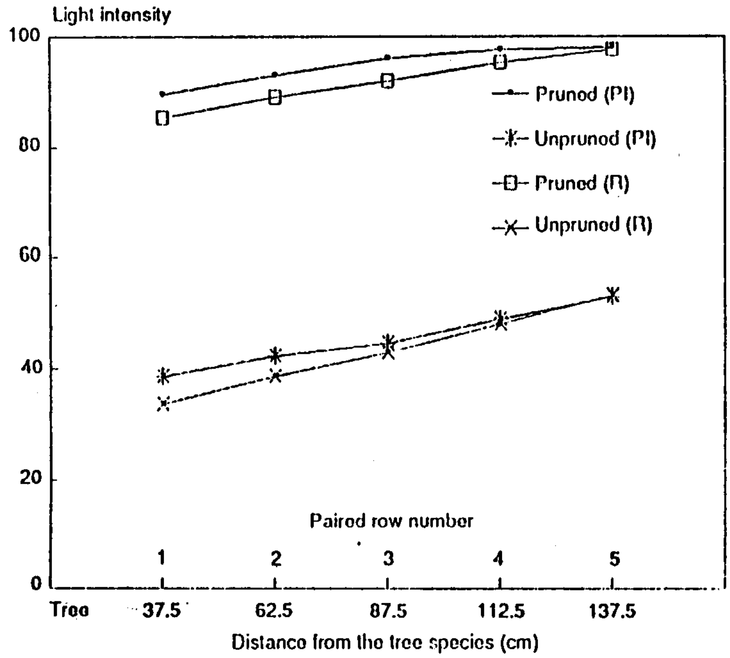

Figure 2. Percent incidence of light on different rice row positions across the alley at panicle initiation (PI) and ripening (R) stages as influenced by tree pruning treatment.

In the unpruned alleys, a severe shading effect was observed throughout the alley, showing 64, 59, 56, 51, and 47% mean reduction in solar radiation in the first, second, third, fourth, and fifth pairs of rows, respectively. In the pruned alleys, the corresponding mean reduction by row was 12.5, 9, 6, 4, and 2%. In the vicinity of the tree rows at both measurement dates, *A. mangium* species showed a higher shading effect under pruned conditions and *A. auriculiformis* had a higher shading effect under unpruned conditions.

2.1.2 Mungbean crop

The mean percent light incidence in the mungbean rows across the alley showed a wide variation in solar radiation availability between pruned and unpruned alleys (Fig. 3). The mean percent light incidence (average of three tree species) in the full alley was only 37 and 36% (at 30 and 50 DAE) in the unpruned alleys, increasing to 91 and 88%, respectively, as a result of pruning. Among the tree species, the mean percent light incidence in the pruned alleys did not vary much (though *G. sepium* had the highest available light at both dates of measurement). In the unpruned alleys, *G. sepium* alleys had about 10 and 21% higher available solar radiation than the other two species at 30 and 50 DAE, respectively. Mungbean rows at the later measurement date (50 DAE) generally experienced lower incident solar radiation regardless of pruning treatment. The values were also higher than in the previous rice crop under the same unpruned conditions. The consistently lower solar radiation at the later stage could be attributed to increase in height and canopy development of the trees. The only *G. sepium* unpruned alleys, however, had higher available solar radiation than that observed at the earlier date (30 DAE). This was due to its unique pattern of leaf shedding during the early dry period, as previously reported by Agboola *et al.* (1982).

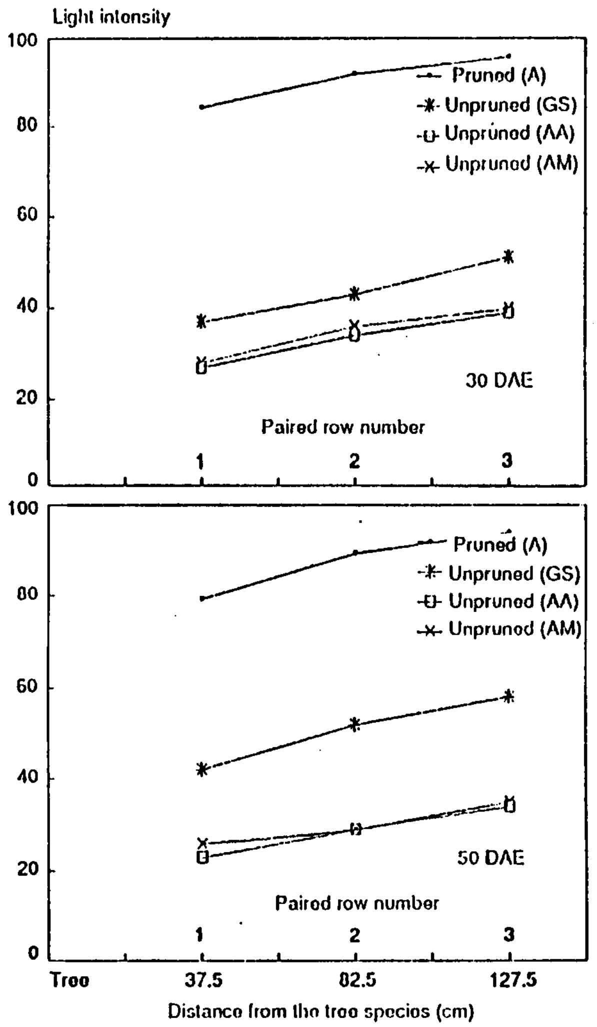

Figure 3. Percent incidence of light on different mungbean row positions across the alley at 30 and 50 days after emergence (DAE) as influenced by tree species and pruning treatment (A= Average of 3 species, GS = *G. sepium*, AA = *A. auriculiformis*, AM = *A. mangium*).

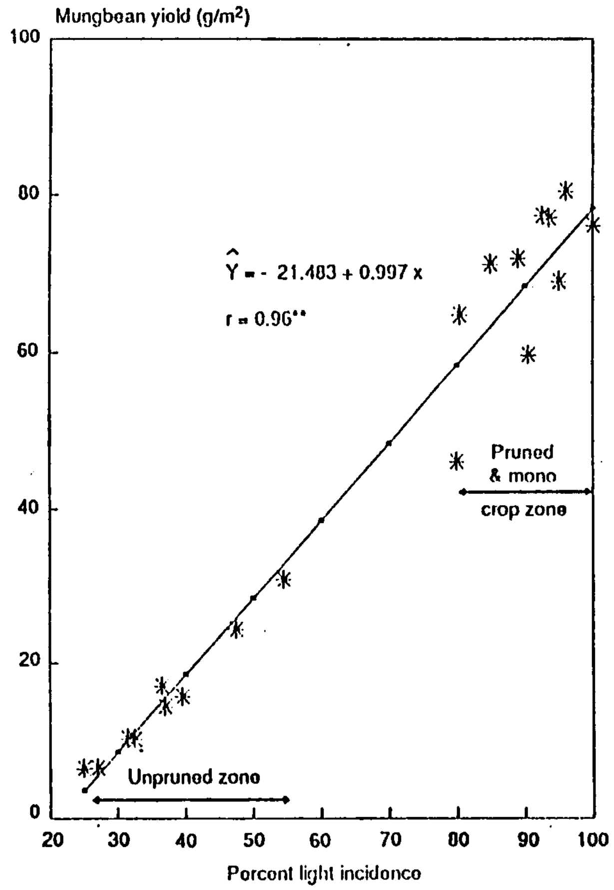

Figure 5. Mungbean yield as a function of percent incidence light under pruned, unpruned and monocrop environments.

Rice yields were much more sensitive to a decrease in percent incident light than were mungbean yields. The greater sensitivity of rice to shading effects was probably due in large measure to differences in the moisture environment between the two crop seasons. The rice experienced uniform and adequate soil moisture availability while mungbeans experienced terminal drought stress. During the mungbean growing season, the total rainfall was only 128.3 mm, of which a significant amount was probably captured by the overstorey trees. Moisture competition was a principal cause of severe reduction in crop yields in the late wet season where rains end abruptly (Lal, 1989; Singh *et. al.*, 1989). Thus, water was evidently a major limiting factor affecting mungbean performance, in addition to light. For the rice crop, water was not limiting and the degree of shading exhibited a stronger negative influence on yields.

There was an interesting contrast in yield response to light as a function of pruning among the two crop species. In rice, pruning reduced the rate of decline in rice yields as a function of relative incident light from 7.34 $g.m^{-2}$ to 6.55 $g.m^{-2}$. In mungbean, pruning increased the rate of yield decline as a function of light incidence from 0.86 $g.m^{-2}$ to 1.40 $g.m^{-2}$. This contrast in

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