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Maize Production under an Intercropping System with Fast-Growing Tree Species: A Case in the Philippines

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Abstract
A maize strain of yellow sweet was intercropped between the four species of fast-growing trees each at Bayog in Los Baños, the Philippines, to examine the effects of intercropping system on maize growth and yield. The tree species planted were: *Gmelina arborea, Paraserianthes falcataria, Acacia mangium and Eucalyptus deglupta.* Two spacings, or 2 × 2 m and 2 × 4 m, were employed in planting trees, and two spacings, or 0.25 × 0.75 m and 0.25 × 2.0 m, were given for a yield trial of maize. In relation to the environmental conditions for growing maize, relative light intensity on the forest floor and basal area were greatly affected by trees' crown, which was closely associated with their branch spread. The largest crown radius took place in G. arborea up to the level of 6 m in plant height. However, it was replaced by P. *falcataria* beyond that level. Under the unclosed intercropping condition, soil temperature of the interrows was lower by 5°C than that of the bared ground in open fields. Plant height and above-the-ground biomass of maize were lowered in accordance with decreasing relative light intensity. Grain yield of maize in the intercropping system with a basal area of less than 0.5 m^2/ha was of the same level as that in the monoculture with a thin density, i.e. 0.25 × 2.0 m. In order to increase crop yields in agroforestry, solar energy has to reach the lower layer of the system as much as possible. Towards this end, it is necessary to remove and/or reduce part of canopy of the upper layer by thinning, pruning and trimming.

Discipline: Forestry and forest products/crop production
Additional key words: above-the-ground biomass, basal area, branch spread, relative light intensity

Introduction

Manuals on agroforestry are already made available[1,6]. However, the recommendations contained in those manuals prepared at the early stage of agroforestry development were based on limited scientific data. In recent years, however, several papers have been published, supplying a great deal of information on the relevant subjects[2–5]. One of the most important issues in designing agroforestry programs is: in what ways could solar energy be adequately shared between the woody plants in the upper layer and the cultivated crops in the lower layer? In this respect, much research still remains to be done yet, including analyses on the relationship between light conditions and crop production under an agroforestry system. This paper deals mainly with the interactions between the growth of fast-growing tree species and the grain yield and biomass production of maize under an intercropping condition.

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Study area

The study area is located at Bayog in Los Baños, Laguna (14°15′ N, 121°20′ E), the Philippines, situated at a distance of about 50 km southeast from Manila along the lake-side of Laguna Bay. It has an annual temperature of 28°C and annual rainfall of about 1,500 mm on an average. A dry season usually continues during the period January to mid May. There is little variation in air-temperature throughout the year. Meteorological data taken in the period November 1986 to October 1987 at the Bayog agroforestry experiment site are shown in Table 1.

The experimental site had been a fallow paddy field for approximately 10 years. Topography, altitude and soil type of the study site are flat on an alluvial plain, around 5 m above sea level and inceptisols, respectively.

Materials and method

Twelve plots were prepared in September 1986 for the study at the Bayog agroforestry experimental site. They consisted of: one plot without any crop cultivation as a control, three plots with a monoculture of maize (*Zea mays*), and eight plots with an intercropping system under which maize plants were grown between the following four fast-growig tree species each: *Gmelina arborea, Acacia mangium, Paraserianthes falcataria* and *Eucalyptus deglupta.* The former two species were planted in three plots each with an initial spacing of 2 × 2 m in November 1986. And the latter two species were planted in one plot each with the same spacing in January 1987. In mid July 1987, in order to widen a tree spacing for the intercropping trial, two plots grown to *G. arborea* and *A. mangium* were subjected to thinning of every other row with two different directions, i.e. one along north–south and the other along east–west; the resultant space in those plots was 2 × 4 m, accordingly. The experimental plots are schematically shown in Fig. 1. Table 2 summarizes planting situations of the experimental plots after thinning. Standing biomass which was estimated on the basis of removed trees in thinned plots is shown in Table 3. Since leaf-biomass in each of the thinned plots was

Table 1. Meteorological data at the Bayog agroforestry experiment site, the Philippines

	1986		1987									
	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.
Rainfall (mm)	157	39	57	0	0	0	50	246	72	143	299	30
Ave. max. tem. (°C)	30.2	28.5	27.7	28.8	31.8	34.4	35.6	33.9	32.9	33.6	33.4	34.9
Ave. min. tem. (°C)	24.5	22.2	21.2	21.3	22.6	24.6	25.5	26.0	25.6	25.5	25.5	26.3

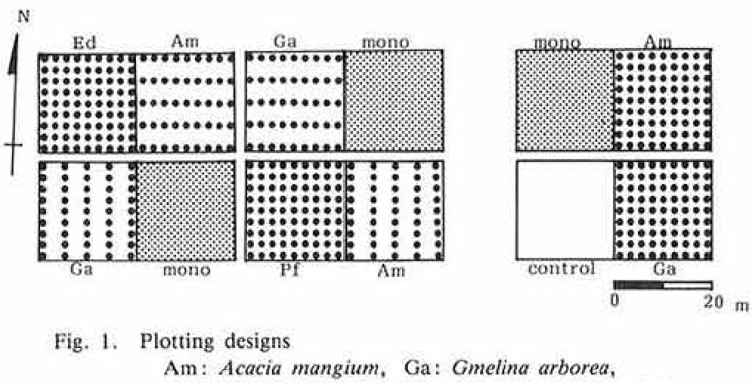

Fig. 1. Plotting designs
Am: *Acacia mangium*, Ga: *Gmelina arborea*,
Pf: *Paraserianthes falcataria*, Ed: *Eucalyptus deglupta*,
mono: monoculture of maize, control: fallow site.

Table 2. Fast-growing tree stands in July 1987

	Thinning[a)]	Data planted	Date of thinning	Density (No./ha)	Height (m)	Doo[b)] (cm)
Acacia mangium	control	25 Nov. 1986		2,500	1.1	1.2
	NS	25 Nov. 1986	16 July 1987	1,250	1.6	1.9
	EW	24 Nov. 1986	17 July 1987	1,250	1.1	1.4
Gmelina arborea	control	25 Nov. 1986		2,500	2.1	3.3
	NS	24 Nov. 1986	17 July 1987	1,250	2.2	3.4
	EW	25 Nov. 1986	16 July 1987	1,250	2.0	3.4
Paraserienthes falcataria	control	12 Jan. 1987		2,500	2.7	3.3
Eucalyptus deglupta	control	12 Jan. 1987		2,500	1.5	2.1

a): Control; Without thinning, NS and EW; Directions of removed rows.
b): Diameter at base.

Table 3. Biomass of thinning stands of *Acacia mangium* and *Gmelina arborea*

Species	Direction of removed rows	Biomass (kg/ha)					
		Stem	Branch	Leaf	Above-ground	Root	Total
A. mangium	North-south	196.4	47.8	229.7	474.0	67.7	541.7
	West-east	96.0	38.9	155.6	290.5	55.1	345.6
G. arborea	North-south	573.4	325.9	761.0	1660.2	313.4	1973.6
	West-east	679.3	331.7	680.3	1691.4	271.0	1962.4

less than 1.0 t/ha just before the tillage for sowing maize, canopy of the tree stands was not completely close. Average tree height, diameter at breast height and crown radius of the planted trees except for edge trees were measured periodically.

At the end of July 1987, a maize strain of yellow sweet was hill-seeded in the middle part between the tree rows for a yield trial. The spacing of maize planting was 0.25 × 0.75 m and 0.25 × 2.0 m in the non-thinned and the thinned plot, respectively. In the monoculture plots, these spacings were both adopted to compare with maize yields under the intercropping system. The dense spacing employed in this study, i.e. 0.25 × 0.75 m, corresponds to the usual planting density for maize cultivation in the Philippines.

After thinning of seedlings of maize, a weeding was undertaken as necessary. Insecticides were sprayed three times on maize plants. No fertilizer was applied to maize in this study because it was deemed difficult to identify potential effects of intercropping of trees on maize growth. The maize plants were matured in mid October. Twenty to 30 plants of maize were harvested so that their biomass and grain yields were measured after oven and air-drying, respectively. Relative light intensity in each plot was calculated as a ratio of the accumulated illuminance on the forest floor to that on the open field.

To compare environmental conditions among the following three sites: (1) the forests with unclosed intercropping stands, (2) the forests with extremely high density stands at the post-nursery bed, or about 40,000 trees/ha of *G. arborea*, and (3) the bare ground of the open field in the experimental site, L-shaped soil thermometers were set at 5 cm depth in each site. Intensity of illumination were measured above the soil thermometers by photometers (Minolta T-1M). Diurnal patterns of illuminance on the forest floor and soil temperature in each site were measured every month after maize sowing.

Results and discussion

1) Growth of fast-growing tree species[7,9)]

Very fast elongation of saplings of the planted trees started at the beginning of the rainy season, or the end May[7)]. In mid July, average tree heights were in the following order: *P. falcataria* > *G. arborea* > *E. deglupta* > *A. mangium*: this order of the plant heights among the tree species was kept until

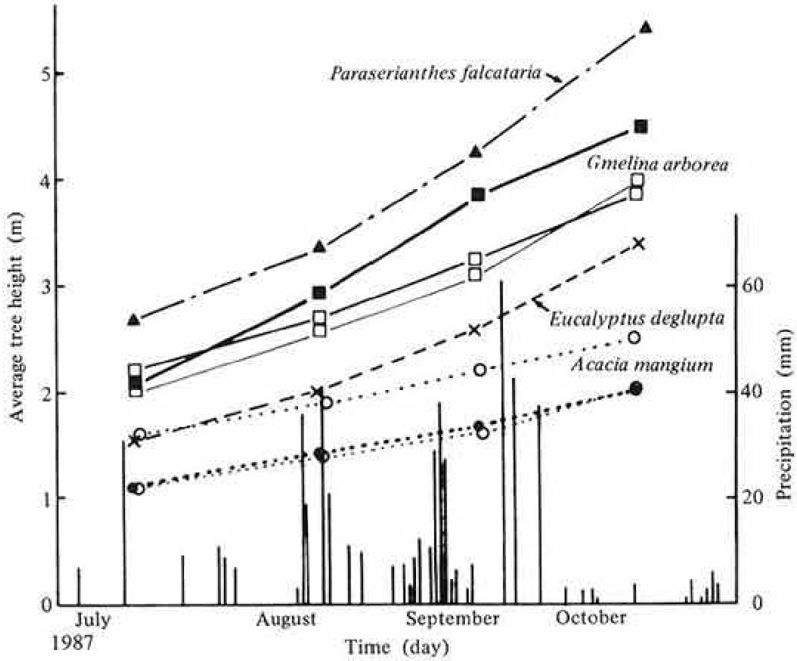

Fig. 2. Changes in average tree height and precipitation pattern
Open circle and square marks denote the plots under thinning.

the end of the relevant study in October. Due to the greater elongation growth in taller species, presenting a monthly increment of about 1 m, larger differences among the species came out in October as shown in Fig. 2. Although the elongation was not significantly affected by thinning, the growth of girth of stems and crown width was accelerated[9].

Fig. 3 shows a relationship of tree growth between the relative light intensity on the forest floor and the basal area at breast height, data on both of which were taken in October. The relative light intensity generally decreased in accordance with the increase of the basal area in all the tree species studied. However, such a distinct relationship was not always seen throughout a year: in fact, the relationship indicated in Fig. 3 was observed in the mid rainy season. And a small amount of leaf biomass usually remains even in the dry season. Therefore, a similar pattern of the relationship, though indistinctive occasionally, also takes place in the dry season, whereby an appropriate control of light condition in the agroforestry system could be designed.

In regard to the branch spread of trees, it usually depends on plant spacing. However, in the competition-free stage, it was primarily subjected to the characteristics of crown formation in the respective tree species. Fig. 4 illustrates relationships between the tree height and the crown radius in the control plots to compare crown sizes of the fast-growing tree species. The largest crown radius was seen in *G. arborea* up to the level of 6 m in plant height. However, it was replaced by *P. falcataria* beyond

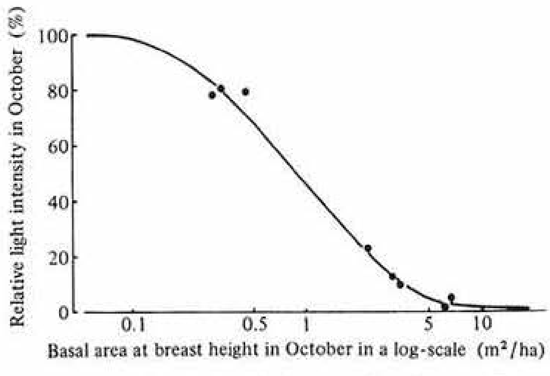

Fig. 3. A relationship between basal area of trees at breast height and relative light intensity in October

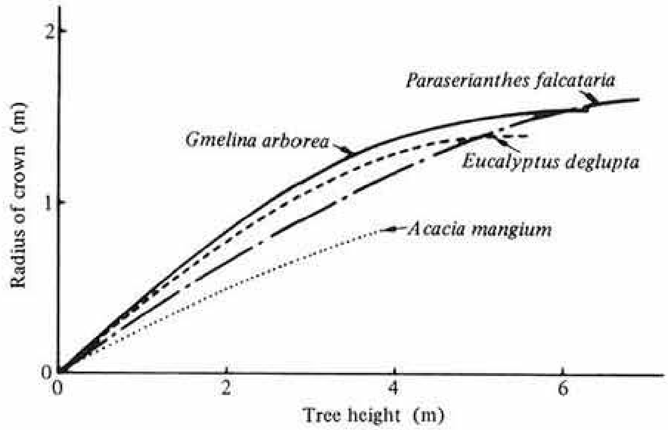

Fig. 4. Relationships between tree height and radius of crown in each control plot

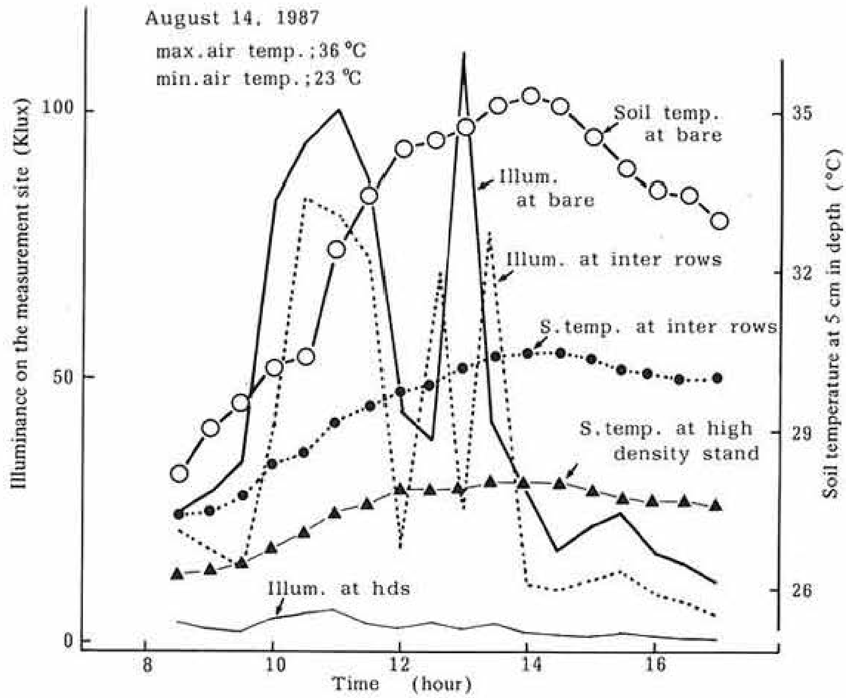

Fig. 5. Diurnal patterns of illuminance on the floor and soil temperature at 5 cm in depth in August
Thick solid, thin solid and dot lines denote measurements taken at bare ground of the open field, under the canopy in high density stands and at mid part between the trees in the intercropping plots, respectively.

that level of plant height. Taking into account such characteristics of branch spread, adequate types of tree species have to be selected to fit an objective and a reqired pattern of agroforestry. It is generally concluded that a species with a slender crown type would be suitable to the intercropping system.

2) Environment under the intercropping system[8)]

Referring to the effects of multistory cropping system on environmental conditions, it was observed that the highest temperature of soil surface reached about 60°C on the bare ground in an open field, while it was 55°C under the multistory system[8)]. This lowered temperature was caused by the crown of upper layer under the multistory system, which provided interception of direct sunlight from time to time.

Diurnal patterns of illuminance on the floor and soil temperature in mid August, when canopy of the intercropping stands was still not closed, are shown in Fig. 5. Illuminance on the forest floor under intercropping greatly fluctuated in the daytime, while soil temperature of the intercropping site was continuously lower by about 5°C than that of the bared ground in open fields which reached 36°C. Under the canopy closure, illuminance on the floor continued to be kept at a low level and soil temperatures were less varied.

In September when the canopy of intercropping stands was closed, there were no significant differences in diurnal pattern of illuminance on the floor and soil temperature between the intercropping stands and the high dense monocropping stands.

3) Plant growth and yields of maize[7)]

Under a shaded condition, the crops under study elongated faster than those in open fields. The plants of groundnuts (*Arachis hypogaea*) grown under the intercropping system showed the tallest height under the light condition of around 20% in relative light intensity (unpublished data). In a month after sowing, plant height of maize intercropped with non-thinned *P. falcataria* and *G. arborea* was relatively tall among others due to change of light quality and to less radiation penetrated through a closed canopy. At the later stage, under the dense crown of *G. arborea*, it became too dark for maize seedlings to grow healthfully, and eventually all of them were dead. In addition, a water logging took place in some plots for two weeks caused by a heavy rainfall in September as shown in Fig. 2. As a consequence, a majority of the maize plants in these plots were seriously damaged: most leaves yellowing, some injuried and even dead.

Fig. 6 illustrates a relationship between the plant height of maize and the relative light intensity in September. The plant height of maize was lowered in accordance with decreasing light intensity. Since cereal crops such as maize are generally susceptible to lodging under a shade condition, a careful management to control light condition is required.

Relationships between the above-the-ground biomass of maize plants and the relative light intensity in October are shown in Fig. 7. In the

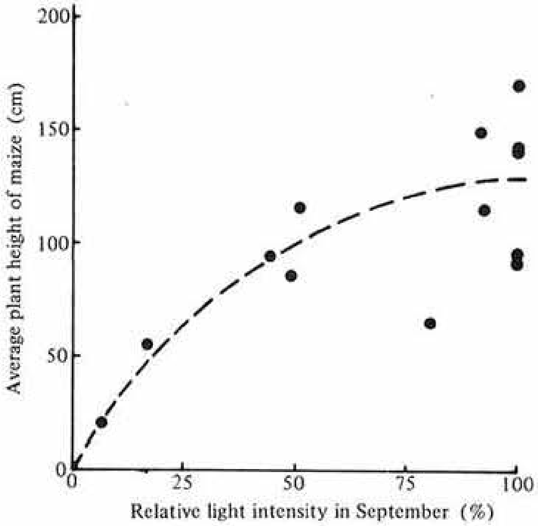

Fig. 6. A relationship between relative light intensity and average plant height of maize in September

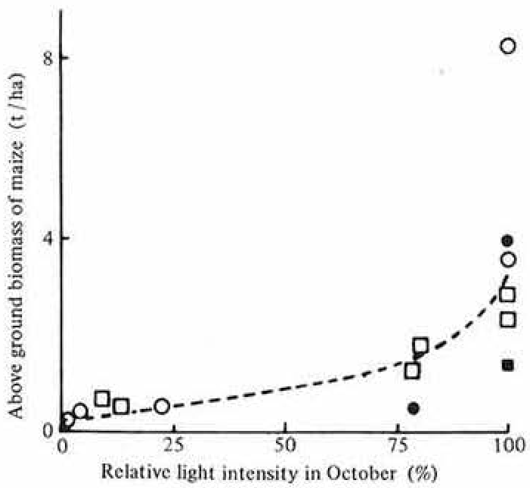

Fig. 7. A relationship between relative light intensity and above-the-ground biomass of maize in October

○, □: High and low density of maize planting, ●, ■: Plots damaged by water logging in each plot.

monoculture plots, a greater biomass of maize plants was produced under the high population density than under the low one. In the intercropping system, however, there was no significant difference in maize biomass production between those two maize spacings, with an exception in the water logging plots.

Fig. 8 shows relationships between the grain yield of maize and the basal area at breast height in October. Under the monoculture condition, higher grain yields were produced in the dense spacing plots. Under the intercropping condition with fast-growing trees, the grain yield of maize intercropped with the thinned stands of *A. mangium*, less than 0.5 m^2/ha of basal area, was of the same level as that under the low density of monoculture maize.

According to the statistics[10], the national average grain yield of maize in the Philippines is about 1.0 t/ha. The highest yield attained in the present study was 1.5 t/ha without any application of fertilizers. Therefore, as far as the yielding level of maize obtained in this experiment was concerned, it was comparable with the national average of maize production. However, quality of the grains, including the harvests in the monoculture plots, was not high enough as compared with the general produce in the Philippines. In managing field crop cultivation under an agroforestry system, great importance should be attached to the quality of the crop produce.

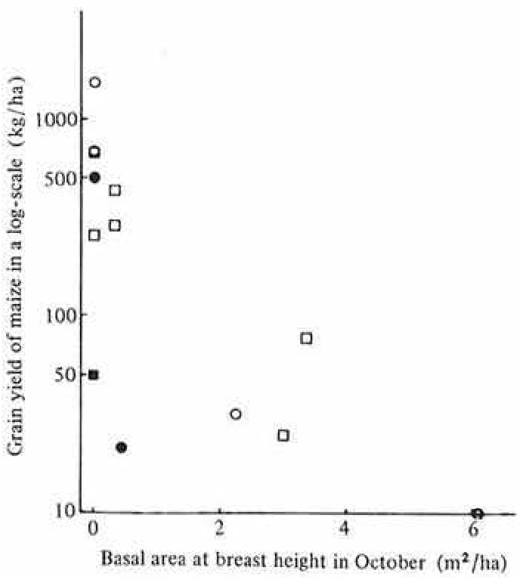

Fig. 8. A relationship between basal area at breast height and grain yield of maize in October Legends are the same as in Fig. 7.

Conclusion

Advantages of adopting an agroforestry system are: (1) to gain economic benefits from woody plants as well as from field crops, and (2) to utilize forest in maintaining and adjusting its environmental functions. In order to increase crop yields in the agroforestry, as identified in the present study, solar energy has to reach the lower layer of the system as much as possible. Toward this end, it is necessary to remove or reduce part of canopy of the upper layer by appropriate measures such as thinning, pruning and trimming. By doing this, however, some disadvantages may be accompanied in the system. It is very likely to take place that in addition to the decreased wood production, the environment adjusting functions of forest such as soil protection, control of water discharge and moderating of the climate, would also be weakened due to the diminished crown density in trees. On the other hand, adequate level of shading provided by tree crown in the upper layer would contribute to increasing dry matter production of crops, owing possibly to recovery of water in the leaves even during the day. Therefore, it may be concluded that one of the key issues for the success of agroforestry centers around balanced use of solar energy by perennial crops; i.e., fast-growing trees and field crops.

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