JARQ 32, 139–144 (1998)

Effect of Shelter Trees on Growth and Yield of Pechai (*Brassica chinensis* L.), Mungbean (*Vigna radiata* L.) and Maize (*Zea mays* L.)

Katsuyuki KATAYAMA*[1], Loretto U. de la CRUZ*[2], Shobu SAKURAI*[3] and Katsuhiro OSUMI*[4]

*[1,4] Marginal Land Research Division, Tropical Agriculture Research Center#
(Tsukuba, Ibaraki, 305-3686 Japan)
*[2] College of Forestry, University of the Philippines
(Los Baños, College, Laguna, the Philippines)
*[3] Department of Research Planning and Coordination, Forestry and Forest Products Research Institute (Tsukuba, Ibaraki, 305-0903 Japan)

Abstract

Field experiments were conducted to determine how shading by shelter trees would influence shoot growth and yield of pechai (*Brassica chinensis* L.), mungbean (*Vigna radiata* L., cv, Pag asa 7) and maize (*Zea mays* L., cv. IPB var. 1). Before sowing of crops, 3 treatments consisting of different relative light intensities (RLI; 100, 88.7 and 24.9%) were prepared without and with the use of shelter trees differing in density in a field at Bayog in Los Baños, the Philippines. Values of leaf number, leaf area, chlorophyll content, shoot dry matter and yield of the 3 crops at 24.9% RLI were significantly lower than those at 100 and 88.7% RLI. Values of specific leaf area (SLA) of the crops, on the other hand, increased significantly at 24.9% RLI. It was observed that there was a difference in yield components between mungbean and maize at 24.9% RLI. Yield of mungbean decreased due to the decrease in the pod number but not in the grain number per pod and grain weight, while that of maize decreased due to the decrease in both kernel number and kernel weight, suggesting that fertilization in maize was more affected by shading than in mungbean. In conclusion, solar radiation is necessary for proper growth and higher yield of crops intercropped with trees. It was suggested that mungbean became better adapred to shading than maize in terms of yield.

Discipline: Crop production
Additional key words: adaptability, agroforestry, intercropping, shade, yield component

Introduction

Increasing population and its associated pressures on agricultural land have threatened tropical forests. Actually, loggers and small-scale farmers are exerting enormous pressures on the upland areas for the production of food, fuel and timber, in the Philippines[9]. These cultivated and deforested areas are vulnerable to soil erosion by rain. If soil erosion develops intensely, these areas are abandoned since cultivation is not possible. On the other hand, soil and climate environments are conserved by afforestation and if crops intercropped with trees are cultivated sustainably.

However, growth performance of crops is affected

This paper reports the results obtained in the collaborative studies on the "Rehabilitation of Degraded Forest Lands through the Implementation of Agroforestry Systems" between the Tropical Agriculture Research Center, Japan and the College of Forestry, University of the Philippines at Los Baños, the Philippines, during the period of July 1992 to November 1992.
Present address:
*[1] Project Research Team 2, National Agriculture Research Center (Tsukuba, Ibaraki, 305–0856 Japan)
*[4] Tohoku Research Center, Forestry and Forest Products Research Institute
(Shimokuriyagawa, Morioka, Iwate, 020–0123 Japan)
Presently: Japan International Research Center for Agricultural Sciences

by trees in terms of utilization of light. Therefore, although most of the studies have dealt with the effect of trimming and spacing of trees on yield of crops[2,12,15], there are very few reports in which the growth characteristics and yield components of crops were analyzed in relation to the light intensity. The purpose of our study was to determine how the yield components of crops can be affected by shading under intercropping conditions.

Materials and methods

1) Study site

The study site was located at Bayog in Los Baños, Laguna (14°15′N, 121°20′E), the Philippines, 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[12]. The dry season usually occurs during the period January to mid-May. There is little variation in air temperature throughout the year. The experimental site had been a fallow paddy field for approximately 10 years. Topography, altitude and soil type of the study site were as follows: flat on an alluvial plain, around 5 m above sea level and inceptisols, respectively[12].

2) Shelter tree arrangement

Three treatments consisting of different light levels were designed in a field with shelter trees. The following 5 fast-growing tree species: *Pterocarpus indicus, Albizia procera, Acacia auriculiformis, Eucalyptus camaldulensis, Samanea saman* were planted before tillage for the sowing of crops. The former 4 species were planted with a spacing of 1.5 × 1.5 m in January 1989, separately[12]. First the field was perpendicularly divided into 4 rectangular areas in a plot. In each area one species of trees predominated. The latter species was planted in 2 plots with a spacing of 2 × 2 m in January 1991. Plot area was 20 × 20 m^2. Stand structure of shelter trees determined on September 16 is shown in Table 1.

3) Cultivation practices

The field was plowed by a carabao (water buffalo) and basal fertilizers were applied to pechai (*Brassica chinensis* L.) and maize (*Zea mays*, L., IPB var.1) at the rate of 31.5 kgN, P_2O_5, and K_2O ha^{-1} using compound fertilizer on July 25, 1992. No fertilizer was applied to mungbean (*Vigna radiata*, L., Pag asa 7) in this study. Three crops were hill-seeded in the middle part between the tree rows for the yield trial on August 1. The spacing of the 3 crops was 0.25 × 0.667 m in the open fields and the *S. saman* plots and 0.25 × 0.75 m in the other plots. There were 2 replications, except for the plot with the 4 tree species. At sowing time, the canopy of *S. saman* was not closed, while that of the other 4 species was almost completely closed. At 14 days after sowing (DAS), seedlings of pechai, maize and mungbean were thinned to 1, 2 and 3 per hill, respectively. After thinning of the seedlings of the 3 crops, weeding was performed as necessary. Insecticides were sprayed 3 times on the 3 crops.

4) Measurement of shoot dry matter at harvest and yield and leaf color

Pechai, mungbean and maize were harvested on October 2, 15, and 25, respectively. Shoot dry matter and yield of mungbean and maize were measured after oven-drying at 70°C and air-drying, respectively. Leaf area was measured using a leaf area apparatus (LI-3100-C, Meiwa). Value of leaf color was measured using a chlorophyll meter (SPAD-502, Minolta).

The data were analyzed by the standard procedures for analysis of variance.

5) Measurement of relative light intensity

Relative light intensity reaching crops in each plot was calculated as the ratio of the accumulated

Table 1. Year of planting (YP), spacing and values of height, radius of canopy (RC) and relative light intensity (RLI) of 5 tree species on September 16

Species	YP	Spacing (m)	Height (cm)	RC (cm)	RLI (%)
P. indicus	1989	1.5 × 1.5	552 ± 181	173 ± 66	16.5 ± 0.0
A. procera	1989	1.5 × 1.5	364 ± 170	123 ± 26	33.5 ± 3.4
A. auriculiformis	1989	1.5 × 1.5	920 ± 194	152 ± 34	24.1 ± 1.2
E. camaldulensis	1989	1.5 × 1.5	510 ± 126	73 ± 54	31.2 ± 3.1
S. saman	1991	2.0 × 2.0	114 ± 14	n.m.[a)]	90.5 ± 1.3

a): Not measured.

illuminance on the forest floor without crops to that on the open field using sun stations (C7A, Kyokko Tsusho) periodically.

Results

1) Changes of relative light intensity

Changes in relative light intensity (RLI) over crops in the absence or presence of intercropping with shelter trees are depicted in Fig. 1. The RLI of the 2 treatments decreased as trees grew. The values of RLI reaching crops in the plots with *S. saman*

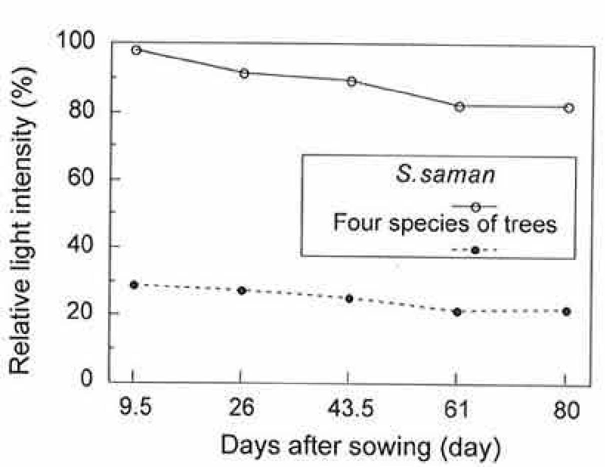

Fig. 1. Changes in relative light intensity reaching crops in the absence or presence of intercropping with shelter trees (100%)

and 4 tree species ranged from 98.3 to 82.6% and from 28.6 to 22.3%, respectively. Therefore, the average values of the RLI in the plot with *S. saman* and 4 tree species were 88.7 and 24.9% during this study, respectively. The RLI in the plot of *S. saman* was larger than that in the plot with the 4 tree species, due to the small crown and short height of the canopy[8] during this study. The canopy of the 4 tree species was almost completely closed. (The average values are listed in the column of RLI in the Tables).

2) Plant height and diameter at base height

The plant height and diameter at base height of mungbean and maize were low at 24.9% RLI, while the plant height-diameter at base height ratio (PDR) at 24.9% RLI significantly increased in maize unlike in mungbean (Tables 3 and 5), indicating that maize had a thinner and taller stem than mungbean under the shade conditions. For pechai, we measured the leaf length since pechai did not develop a stem yet. There was no significant difference in the leaf length of pechai among the treatments (Table 2).

3) Leaf production, morphology and chlorophyll content

Leaf number of the 3 crops at 24.9% RLI was significantly lower than in the other 2 treatments (Tables 2, 3 and 5), indicating that the rate of leaf

Table 2. Values of leaf length (LL), leaf number (LN), leaf size (LS), specific leaf area (SLA) and green meter (GM), shoot dry matter per plant (SDM) and yield per plant (YPP) of pechai at different relative light intensities (RLI) at harvest

RLI (%)	LL (cm)	LN	LS (cm^2)	SLA (cm^2/g)	GM	SDM (g/pl)	YPP (g/pl)
100	22.6 ± 1.2	10.6 ± 0.6	78.9 ± 1.1	252 ± 40	37.0 ± 2.4	5.82 ± 0.46	59.3 ± 4.7
88.7	21.2 ± 4.2	12.0 ± 2.0	64.8 ± 19.1	254 ± 26	37.5 ± 3.1	5.18 ± 1.10	57.4 ± 12.2
24.9	16.2 ± 3.0	5.2 ± 1.3	30.9 ± 5.5	472 ± 85	26.2 ± 0.6	0.50 ± 0.25	6.9 ± 3.5
SE(±)	1.5^{ns}	0.5*	2.5*	16*	0.8*	0.08*	0.8**

*,** Significant at P<0.05 and 0.01, respectively. ^{ns}: Not significant.

Table 3. Values of plant height (PH), diameter at base height (D), plant height-diameter at base height ratio (PDR), leaf number (LN), leaf size (LS), SLA, green meter (GM) of mungbean at different RLIs at harvest

RLI (%)	PH (cm)	D (mm)	PDR (cm/mm)	LN	LS (cm^2)	SLA (cm^2/g)	GM
100	56.4 ± 3.6	5.6 ± 0.2	10.1 ± 0.2	18.3 ± 3.3	22.9 ± 2.1	156 ± 5	46.0 ± 2.6
88.7	56.6 ± 0.9	5.8 ± 0.1	9.7 ± 0.4	19.4 ± 1.9	24.2 ± 1.2	174 ± 4	46.6 ± 0.1
24.9	30.2 ± 3.9	2.6 ± 0.6	11.5 ± 1.0	10.9 ± 2.4	9.1 ± 1.6	328 ± 25	33.8 ± 1.4
SE(±)	2.7*	0.3*	0.48^{ns}	0.5*	1.4*	10**	0.6**

*,** Significant at P<0.05 and 0.01, respectively. ^{ns}: Not significant.

production may be low and that the values of the leaf size of the 3 crops decreased significantly at 24.9% RLI. On the other hand, values of specific leaf area (leaf area / leaf dry weight; SLA) of the 3 crops increased significantly at 24.9% RLI (Tables 2, 3 and 5).

4) Shoot dry matter, yield and yield components

Shoot dry matter of the 3 crops at 24.9% RLI was significantly lower than that in the other 2 treatments (Tables 2, 4 and 6).

Yield of the 3 crops decreased significantly at 24.9% RLI due to the reduction of the leaf number and leaf size in pechai, pod number in mungbean and kernel number and kernel weight in maize (Tables 2, 4 and 6).

The quality of pechai was poor at 24.9% RLI since the leaf size was small and leaf color was light (Table 2).

Discussion

Growth of crops was affected by the changes in the light intensity and low radiation that penetrated through the closed canopy. At 24.9% RLI, dry matter production of the 3 crops was significantly lower than in the other treatments. Leaf production of the 3 crops also decreased significantly at 24.9% RLI. It has been reported that the rate of leaf production was low in lettuce[5] and broad bean[18] under shade conditions. On the other hand, SLA of the 3 crops increased significantly at 24.9% RLI. The production of broad leaves is a common characteristic of plants growing in natural shady environments, presumably because the light interception increases[1]. Wolff and Coltman[17] also reported that the SLA

Table 4. Values of shoot dry matter per plant (SDM), pod number (PN), grain number per pod (GNPP), grain weight (GW), yield per plant (YPP) of mungbean at different RLIs at harvest

RLI (%)	SDM (g/pl)	PN	GNPP (mg)	GW	YPP (g/pl)
100	13.8 ± 0.1	13.2 ± 1.2	7.0 ± 0.8	50.2 ± 0.2	3.94 ± 0.1
88.7	12.8 ± 0.7	12.8 ± 2.1	6.5 ± 1.4	49.3 ± 0.3	3.76 ± 0.2
24.9	1.9 ± 0.3	1.8 ± 0.3	7.4 ± 0.8	46.7 ± 2.4	0.62 ± 0.1
SE(±)	0.4*	0.9*	0.8^{ns}	1.1^{ns}	0.12**

*,** Significant at $P<0.05$ and 0.01, respectively. ^{ns}: Not significant.

Table 5. Values of plant height (PH), diameter at base height (D), plant height-diameter at base height ratio (PDR), leaf number (LN), leaf size (LS), SLA, green meter (GM) of maize at different RLIs at harvest

RLI (%)	PH (cm)	D (mm)	PDR (cm/mm)	LN	LS (cm^2)	SLA (cm^2/g)	GM
100	174 ± 6	13.4 ± 0.4	13.0 ± 0.1	9.4 ± 0.2	253 ± 34	185 ± 12	43.6 ± 2.1
88.7	156 ± 8	12.2 ± 1.8	12.9 ± 1.3	8.7 ± 0.6	252 ± 72	189 ± 1	40.3 ± 2.5
24.9	104 ± 12	5.1 ± 1.3	20.3 ± 1.5	7.0 ± 1.2	77 ± 8	325 ± 26	31.2 ± 1.3
SE(±)	5*	0.8*	0.5*	0.2*	11.0*	5**	1.0*

*,** Significant at $P<0.05$ and 0.01, respectively.

Table 6. Values of shoot dry matter per plant (SDM), kernel number per cob (KNPC), kernel weight (KW), yield per plant (YPP) of maize at different RLIs at harvest

RLI (%)	SDM (g/pl)	KNPC	KW (mg)	YPP (g/pl)
100	68.8 ± 4.9	181 ± 11	109 ± 9	19.7 ± 2.9
88.7	52.5 ± 3.2	189 ± 34	88 ± 3	16.3 ± 3.4
24.9	7.4 ± 1.4	0 ± 0	0 ± 0	0 ± 0
SE(±)	2.0**	17*	5*	2.2*

*,** Significant at $P<0.05$ and 0.01, respectively.

of 6 leafy vegetable crops increased by the increase in shading. In spite of this adaptation to shading, the leaf size of the 3 crops at 24.9% RLI was significantly smaller than that in the other 2 treatments (Tables 2, 3 and 5). These results indicate that these crops display a limited genetic ability for morphological adaptation to shading.

Moreover, the values of the chlorophyll content of the 3 crops decreased significantly at 24.9% RLI (Tables 2, 3 and 5). We assumed that the low production of dry matter at 24.9% RLI was due to the reduction of the rate of photosynthesis associated with the decrease in the chlorophyll content of the leaf and light intensity.

These results suggested that based on the growth of the 3 crops at 24.9% RLI there was a limitation of adaptation to shading.

Regarding the yield components of mungbean, grain yield was associated with the pod number but not with the grain number per pod and grain weight. Similar results were obtained in soybean[13], beans[10], and broad bean[18] under shade conditions.

In maize, kernel number per cob[3,4,7,11] and kernel weight[14] decreased during the reproductive period by shading. The yield production of kernel per cob was affected mostly at an illumination of less than 40%[3]. Moreover, Reed et al.[11] and Hashemi-Dezfouli and Herbert[6] reported that kernel abortion in maize increased by shading. In our study, maize yield was 0 at 24.9% RLI since all the kernels were empty, presumably due to the reduction of assimilate supply to the developing ear associated with the reduction of photosynthesis. It was suggested that mungbean was better adapted to shading than maize since filling of mungbean pods occurred under the shade conditions unlike that of maize kernels.

In conclusion, solar radiation is necessary for high yield and proper growth of crops intercropped with trees. It was reported that light was a critical limiting factor in the competition in intercropping[16]. Sato et al.[12] suggested that it was necessary to remove or reduce part of the canopy of the upper layer by appropriate measures such as thinning, pruning and trimming to enable crops in the lower layer to receive as much light as possible. Duguma et al.[2] also observed that higher maize and cowpea yields were obtained with increasing pruning frequency and decreasing pruning height.

Therefore, it is essential to promote careful management to control the light conditions and to identify suitable crops for intercropping with shelter trees.

References

1) Boardman, N. K. (1977): Comparative photosynthesis of sun and shade plants. *Ann. Rev. Plant Physiol.*, **28**, 355-377.
2) Duguma, B. et al. (1988): Effect of pruning intensities of three woody leguminous species grown in alley cropping with maize and cowpea on an alfisol. *Agrofor. Sys.*, **6**, 19-35.
3) Early, E. B. et al. (1966): Effects of shade on maize production under field conditions. *Crop Sci.*, **6**, 1-7.
4) Early, E. B. et al. (1967): Effects of shade applied at different stages of plant development on corn (*Zea mays* L.) production. *Crop Sci.*, **7**, 151-156.
5) Gray, D. & Dteckel, J. R. A. (1981): Heating and mature head characteristics of lettuce (*Lactuca sativa* L.) as affected by shading at different periods during growth. *J. Hort. Sci.*, **56**(3), 199-206.
6) Hashemi-Dezfouli, A. & Herbert, S. J. (1992): Intensifying plant density response of corn with artificial shade. *Agron. J.*, **84**, 547-551.
7) Kiniry, J. R. & Ritchie, J. T. (1985): Shade-sensitive interval of kernel number of maize. *Agron. J.*, **77**, 711-715.
8) Lawson, T. L. & Kang, B. T. (1990): Yield of maize and cowpea in an alley cropping system in relation to available light. *Agric. For. Meterol.*, **52**, 347-357.
9) Maclean, R. H. et al. (1992): The impact of alley cropping *Gliricidia sepium* and *Cassia spectabilis* on upland rice and maize production. *Agrofor. Sys.*, **20**, 213-228.
10) Portes, T. de A. & Silveira, P. M. da (1982): Effect of artificial shade on morphological characteristics and seed production in beans (*Phaseolus vulgaris* L.). Goiania, Brazil, Centro Nacional de Pesquisa-Arroz, Feijao, 151-153.
11) Reed, A. J. et al. (1988): Shading effects on dry matter and nitrogen partitioning, kernel number, and yield of maize. *Crop Sci.*, **28**, 819-825.
12) Sato, A. & Dalmacio, R. V. (1991): Maize production under an intercropping system with fast-growing tree species: a case in the Philippines. *JARQ*, **24**, 319-326.
13) Tanaka, A. et al. (1980): Effect of shading on dinitrogen fixation and combined nitrogen absorption in soybean. *J. Sci. Soil Manure, Jpn.*, **51**(4), 281-284 [In Japanese].
14) Tollenaar, M. (1977): Sink-source relationships during reproductive development in maize. *Review Maydica*, **22**, 49-75.
15) Torres, F. (1983): Role of woody perennials in animal agroforestry. *Agrofor. Sys.*, **1**, 131-163.
16) Verinumbe, I. & Okali, D. U. U. (1985): The influence of coppiced teak (*Tectona grandis* L.F.) regrowth and roots on intercropped maize (*Zea mays* L.). *Agrofor. Sys.*, **3**, 381-386.
17) Wolff, X. Y. & Coltman, R. R. (1990): Productivity of eight leafy vegetable crops grown under shade in Hawaii. *J. Amer. Soc. Hort. Sci.*, **115**(1), 182-188.

18) Xia, M. Z. (1987): Effect of various light intensities on nitrogen fixation and sugar distribution of broad bean. *Pl. Physiol. Comm.*, **3**, 21–23.

(Received for publication, June 12, 1997)