Growth and Yields of Field Crops in Intercropping Culture

By TAKATSUGU HORIUCHI

Faculty of Agriculture, Gifu University
(Yanagido, Gifu, 501-11 Japan)

Intercropping culture is a popular cropping system practiced in countries with abundant farming labor like some developing countries in the world. In Japan, this cropping system can be rarely seen as an age-old method of intensive cultivation practiced mainly in small-sized fields, mostly 30 a for self-sufficiency of farmers. Notwithstanding this situation, it seems that the intercropping culture still possesses a great deal of effectiveness for obtaining rational income from the viewpoint of farm managements including natural and social dimensions such as effective land use and dispersion of damage caused by natural or economic hazards.[1,5,7,8] Nowadays, this cropping system is receiving a more attention in some developed countries. In this paper, results of some experiments carried out on intercropping methods as a fundamental study to find out planting patterns suitable for modern agriculture in Japan will be described.

One of the most realizable means to save labor in intercropping culture is to establish a suitable planting arrangement of component crops, of which growth characteristics have to be exactly grasped. For this purpose, experiments on factors which influence greatly the growth and yield of each component crop have been carried out since 1978.

Effects of plant type, sowing time and planting density on growth and yields

Maize-kidney bean intercropping is one of the most popular crop combinations in rural areas of Japan. According to the field surveys done by the author on the intercropping cultivation in different regions during the period from 1978 to 1984, plant type and sowing time of kidney bean were different among the regions, though those of maize generally constant.

In relation to this point, a field experiment was carried out in 1979[2] by using the maize (sweet corn)-kidney bean combination (an intra-row mixed cropping*) to determine the effects of plant type and sowing time of bean and also of planting density on growth and yields of each component crop. The results obtained are summarized as follows:

Plant height of maize tended to increase after tasseling at higher planting densities, irrespective of the different plant types and sowing times of the bean. At the high planting density under the intercropping condition, plant height of the bean of pole type became remarkably short by late sowing but that of dwarf type tended to become taller by late sowing.

Weed emergence was greatly restricted at higher planting density of intercropping. The weed growth was dependent on the degree of light transmission into the plant community, that is, active growth of weeds could be seen under the condition of higher light intensity at the sparse planting.

Grain yield per maize plant was low at higher planting density, irrespective of the difference of plant types of the bean. The higher grain yield per plot was obtained by the combination with the dwarf type bean than with pole type bean. Yields per area were higher at higher planting density in any plot but the increment rate was small in the intercropping. On the other hand, yield per plant of kidney bean showed different tendency among the plots by their plant types and different sowing times, though the yield per area tended to be higher at higher planting

* Maize and kidney bean were alternatively planted in a row, and hence the planting density of each crop was the same.

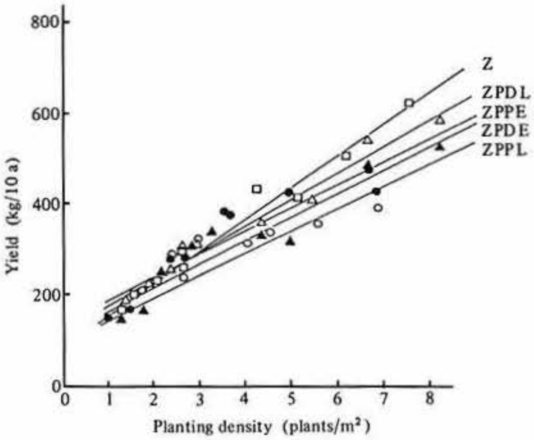

Fig. 1. Yield of single-cropped or intercropped maize at different planting densities
Z: maize
PD: kidney bean (dwarf type)
PP: kidney bean (pole type)
E: early sowing of kidney bean
L: late sowing of kidney bean

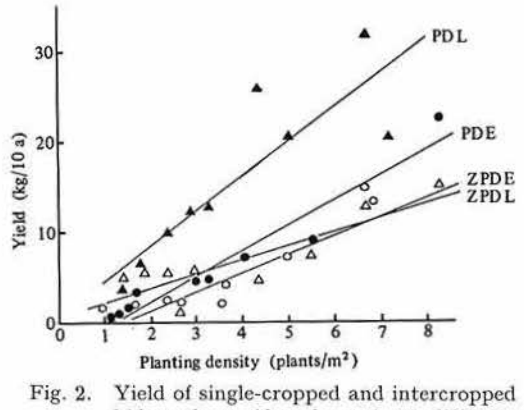

Fig. 2. Yield of single-cropped and intercropped kidney bean (dwarf type) at different planting densities

density in any plot. The yield per area of kidney bean in the intercropping plots was low for early sowing of pole type bean and late sowing of dwarf type bean (Figs. 1–3).

Presuming from the evaluation of intercropping-effects by relative yield totals (RYT),[6] any of the intercropping patterns have high advantages in land use as compared with the single cropping. The maximum value of RYT was found at the higher planting density with late sowing of pole type bean and at the lower planting density with early sowing of dwarf type bean (Fig. 4).

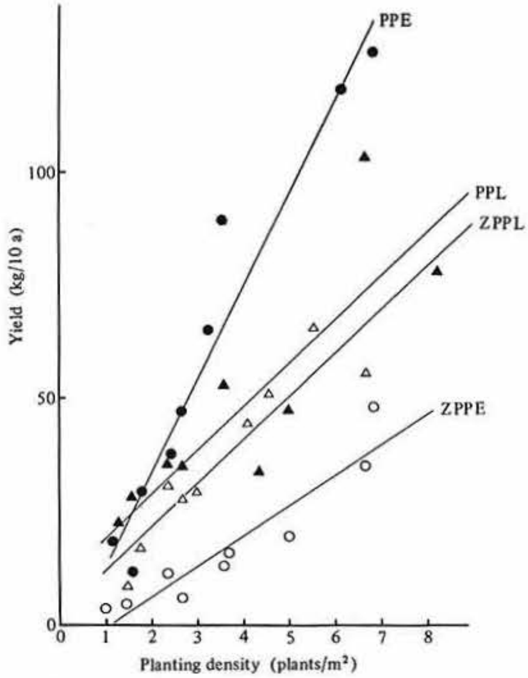

Fig. 3. Yield of single-cropped or intercropped kidney bean (pole type) at different planting densities

The results indicate that plant type, sowing time and planting density are important elements influencing the growth and yields of component crops in the intercropping culture, though the cultural management is troublesome, especially at the higher planting density because the used planting pattern was in-row planting.

Effects of the number of component crops on growth and yields

The number of component crops is ordinarily two in the intercropping culture of farmers' fields, but the author found the case with three crops (maize, kidney bean–dwarf type and Japanese radish) at highland of HIDA area at an elevation of 1,300 m above sea level. In any highland or higher latitude region with a short period available for plant growth, an efficient land use is generally required, especially in small scale farming, for obtaining higher crop production. An experiment[3] to examine the possibility of more efficient land use was carried out by

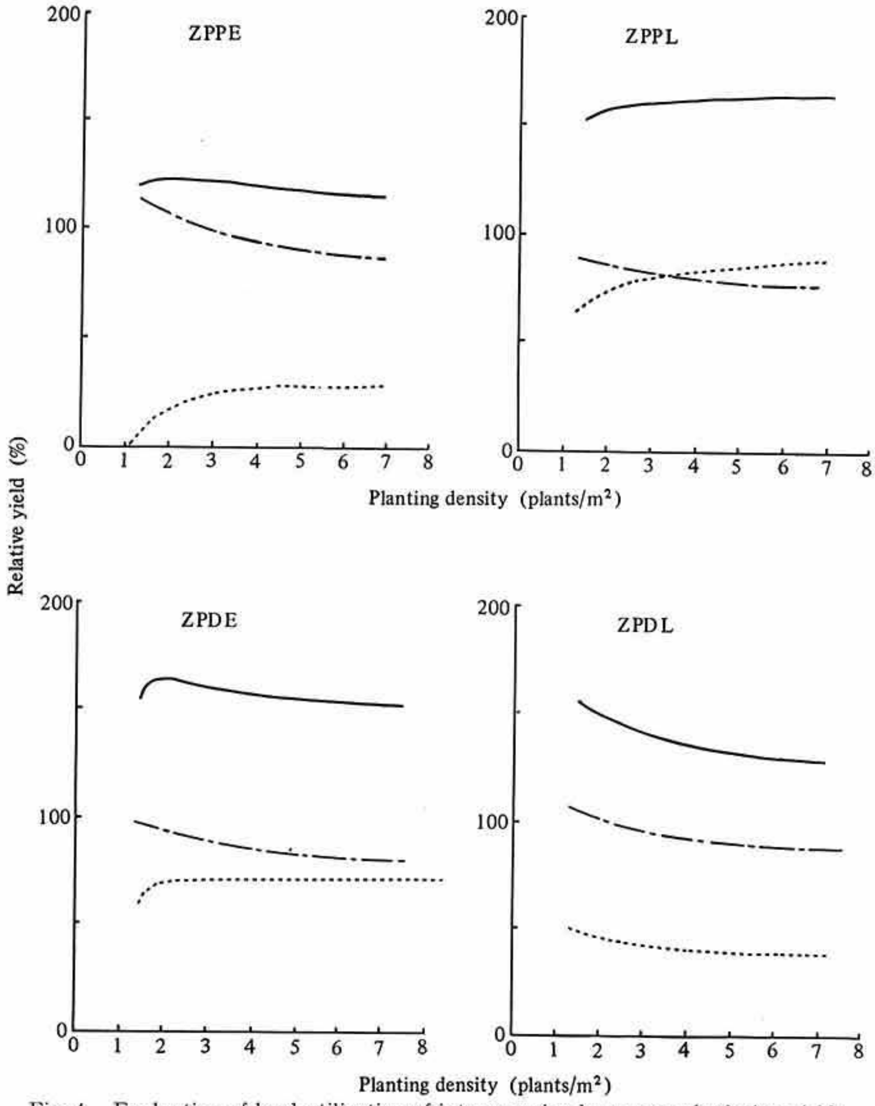

Fig. 4. Evaluation of land utilization of intercropping by means of relative yields
———— : Total of relative yield of maize and kidney bean
—·—·— : Relative yield of maize
----------- : Relative yield of kidney bean

utilizing three component crops, Japanese yam, maize, and kidney bean, as the experimental materials in 1980. The experiment was designed to find out a rational crop combination (an intra-row intercropping) in the field of Japanese yam as a main crop. Three plots, i.e. single cropping of Japanese yam (D), intercropping of maize and Japanese yam (ZD) and maize, kidney bean and Japanese yam (ZPD) were prepared. The results were as follows:

Relative light intensity measured at the height of 1 m above the soil surface of inter-hill spaces in the plant community, at ripening stage of maize and also flowering stage of kidney bean was lower in ZPD and ZD plot than that of D plot and this tendency was remarkable in the former. The tuber yield of Japanese yam was signficantly higher in the single cropping plot D than in ZD and ZPD plots, both of which produced small sized tubers with a poor quality,

Table 1. Tuber yield and tuber size of Japanese yam

Plot	Tuber weight (g)	Size (cm)		
		Length	Width	Thickness
ZPD	107.4 b	7.5	6.0	4.6
ZD	121.6 ab	8.0	6.3	6.5
D	133.3 a	8.6	6.5	4.8

Figures followed by a common letter are significantly different at the 5% level by Duncan's New Multiple Range Test.

showing no difference in the tuber yields between them, as shown in Table 1. As to the grain yields of maize, no significant difference was recognized though the yield of ZD appeared to be higher than that of ZPD. The total of the grain yield of maize and the tuber yield of Japanese yam in ZD plot showed a substantial increase of production per plot as compared with D plot, indicating a high efficiency of land use by intercropping of Japanese yam and maize.

Evaluation of the land use efficiency in terms of calorie of harvested crops, which was measured by bomb calorimeter, showed that the calorie production was notably higher in the intercropping plots than in the single cropping plot of Japanese yam. Between the intercropping plots, no difference was noted. Thus, the selection of kinds and number of component crops is important in saving investments including farm labor and in securing good quality of products.

Effects of planting patterns in different crop combinations on growth and yields

In this experiment,[4] two types of crop combination, i.e. maize+soybean (Z group) and taro+soybean (C group), were prepared by growing each individual plant in a pot and by making necessary arrangements of the pots, simulating the Z and C intercroppings. The Z group has the following 4 plots;

- Z1: One row of maize was alternated with one row of soybean.
- Z3: Three rows of maize were alternated with three rows of soybean.
- Z1-3: At the flowering stage of the soybean, Z1 arrangement was changed to Z3 arrangement.

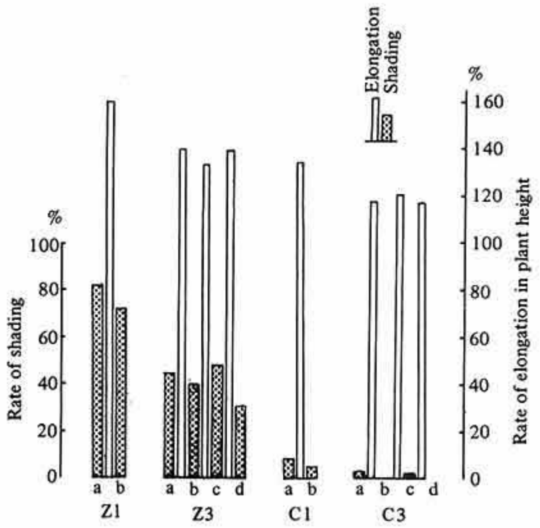

Fig. 5. Rate of shading over the soybean canopy and rate of elongation in plant height of soybean in the maize + soybean (Z) and taro + soybean (C) intercropping cultures
a, b, c, d: sites for measuring light intensity

- Z3–1: Z3 arrangement was changed to Z1 arrangement at the same time as above.

Similarly, the C group has C1, C3, C1-3, and C3-1 plots. The results obtained are as follows:

Growth: Maize showed no differences in plant height between Z1 and Z3. On the other hand, plant height of taro was higher in C3 than C1. The taro in C3 showed more mutual shading than in C1 during the drought which occurred in early July (an early growth period). In this case, there was little mutual shading in C1. In the later growth stage, the number of active leaves of taro decreased due to plant aging, and which induced luxuriant growth of soybean. Plant height of soybean tended to be higher in Z than in C throughout the whole growth period, and also tended to be higher in the following order, i.e. Z1, Z1-3>Z3-1, Z3 and C1, C1-3>C3-1, C3. The rate of elongation of plant was remarkably higher at the early growth stage and decreased with the advance of growth (Fig. 5). Therefore, as far as plant height is concerned there was no difference between Z1 and Z1-3, Z3 and Z3-1, C1 and C1-3, and C3 and C3-1. This result shows that the change of intercropping pattern

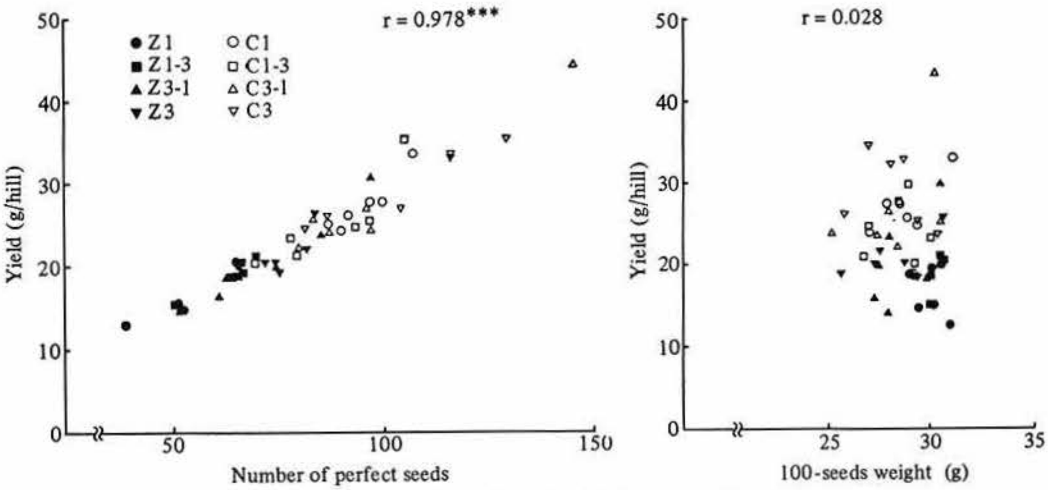

Fig. 6. Correlation between yields and number of perfect seeds or 100-seeds weight of soybean

given after the flowering stage of soybean hardly influenced the plant height of soybean.

Relative light intensity (Fig. 5) of the plant community was measured to compare the light condition among the plots. As a result, it was found out that the light intensity was influenced to a great extent by the different planting patterns in each crop combination. That is, light transmission rate was higher in Z3 plot than in Z1 plot at an early growth stage of soybean because of the vigorous growth of maize in Z1 plot. But this rate became higher in Z1 than Z3 at the ripening stage due to scensence of maize leaves. The degree of shading in plant community of C group was lower than that of Z group because growth velocity of taro was slower than that of maize at an early growth stage, but light intensity became higher at the late growth stage by the same reason observed on maize.

Yield: Maize grain yield and its yield components were not significantly different among the plots. Taro tended to be high in tuber weight in C3 than in C1 due to its less mutual shading caused by a dry condition during summer season. As to the grain yield of soybean and its yield components, it was observed that weight of perfect seeds was greater in the C group than in the Z group as shown in Fig. 6. In each group, 1 and 1-3 tended to show lower values than 3 and 3-1, and the value of 1 was similar to 1-3 and that of 3 to 3-1. It suggests that the critical time for obtaining high yields of soybean is the early growth stage so that the shading by neighboring crop at that stage reduces grain yield. As mentioned above, the yields of soybean were significantly lower in the intercropping plots with maize than in those with taro. These yields were not determined by 100 seeds weight, but the number of perfect seeds (Fig. 6). The number of perfect seeds showed a high correlation with the percentage of perfect pods in the Z group, but not in the C group. This result means that the amount of photosynthetic production was not enough to support the growth of all pods to perfect pods, when soybean was intercropped with maize. Therefore, in a crop combination suitable sowing time for both crops should be searched for in order to obtain good yields without severe competition between component crops for light and nutrient.

Conclusion

These experimental results suggest that the yields of component crops are greatly dependent upon their growth conditions during the overlapping period of cultivation. The length of overlapping duration is determined by crop combination including the difference of sowing time and distinction of early or late maturing habit of crops. However, what crop combination is to be used depends upon the grower's intention for

Table 2. Frequencies of crop combinations (in plant family) found in farmers' fields (from 1978 to 1984)

Crop combination	Fequency (%)
Gramineae + *Leguminosae*	23.5
Gramineae + *Cruciferae*	11.8
Leguminosae + *Theaceae*	5.9
Gramineae + *Cucurbitaceae*	5.9
Gramineae + *Solanaceae*	3.9
Leguminosae + *Solanaceae*	3.9
Araceae + *Theaceae*	3.9
Gramineae + *Araceae*	3.9
Gramineae + *Liliaceae*	3.9
Gramineae + *Umbelliferae*	2.0
Gramineae + *Convolvulaceae*	2.0
Gramineae + *Gramineae*	2.0
Gramineae + *Zingiberaceae*	2.0
Leguminosae + *Araceae*	2.0
Lequminosae + *Dioscoreaceae*	2.0
Lequminosae + *Labiatae*	2.0
Leguminosae + *Cruciferae*	2.0
Araceae + *Labiatae*	2.0
Araceae + *Moraceae*	2.0
Cruciferae + *Theaceae*	2.0
Cruciferae + *Araliaceae*	2.0
Dioscoreaceae + *Zingiberaceae*	2.0
Leguminosae + Perennial plant	2.0
Araceae + Perennial plant	2.0

crop production. The purpose of intercropping is diverse, for example, some crops require an overlapping in a certain period of growth stage to keep good quality of their product, like ginger with intercropped maize, to lessen drought damage of crops which are less tolerable to drought like taro, and also to maintain the soil fertility by using green manure crops like oats and rye for the perennial crops such as asparagus (Table 2). Therefore, technical improvements which can be expected to reduce the competition between component crops for light in the plant community and for nutrition or water in the soil should be employed, after the kind of crops to be grown is appropriately selected by considering social conditions such as labor availability, demand and supply relations, market price of products and so on, in addition to natural conditions.

By taking account of the potentiality of saving labor and the feasibility of farm mechanization, it seems that the most useful planting pattern may be strip or alternative intercropping which is regarded to be situated in the course of development from the primitive and irregular mixed cropping to the simple single planting.

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