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Studies on the Interaction Between Upland Rice and Other Crops in Intercropping System

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Keywords: upland rice, intercropping, replacement series.

Abstract

The national rice requirement in Indonesia today is very high, and can not be fullfiled from irrigated lowland rice area only. However, the contribution of upland rice, which is grown in dryland and rainfed area, to national rice production is lower compared to lowland rice, although dryland area in Indonesia is much wider compared to lowland area. One of the advantages of upland rice culture compared to lowland rice is that it can be grown side by side with other crops under intercropping system. Studies on the interaction between upland rice and other crops is needed to get the crops suited to grow together.

This paper is a review of the results of a series of field experiments on the intercropping between upland rice and other (legume and horticultural) crops conducted in agriculture experiment station, Gadjah Mada University, in Kalitirto district, Yogyakarta, from 2000 up to 2005. The methodology used is based on the replacement series technique. Basically, there are three different types of interaction, i.e. (1) Mutual inhibitation, when the actual yield of each species is less than expected. (2) Mutual cooperation or complementation, when the actual yield of each species is greater than expected. (3) Compensation, one species yield is less and the other is more than expected.

The results of the experiments was classified into two groups i.e. (1) upland rice vs legume crops and (2) upland rice vs horticultural crops. Most of legume crops stimulated upland rice yield. However, the effect of upland rice on each legume was different, i.e. decreased yield such as in mung bean and groundnut, or no significant effect such as in velvet bean (*Mucuna sp.*). Thus a compensation type of interaction occurred. In horticultural crops, the results varied depending on the species of the crop. Complementary was shown on the interaction between upland rice and water melon. In intercropping upland rice-onion, upland rice stimulated onion yield while onion did not affect to upland rice yield. However, in intercropping upland rice-pineapple, both Cayenne and Queen types of pineapple gave positive effect (increased) to upland rice yield, while upland rice did not give harmful effect to pineapple.

I. Introduction

Formerly the Indonesian economic development was directed to industrial sector in which most of the resource materials were imported. Consequently the agricultural sector was left behind, and in 1998 the government imported 5.8 millions tons of rice which costed Rp. 10.44 trillions (Muhtadi, 1999; Karama, 2000). Today the food reserves policy is focused on to fulfils rice requirement based on national production i.e. equal to 54,259,400 tons paddy per year to fulfil the need of about 210 millions people. The efforts on fulfiling the rice requirement can not be reached by intensification in the irrigated area only. Especially in Java island, because of its high population pressure, many irrigated lands change to non agricultural land, which means the decrease of land with high productivity (Suyana, 2000).

There are about 7.5 millions hectares rainfed area in Indonesia, however only 2.5 millions hectares have been developed for rice culture, i.e. 293,960 hectares in West Java, 358,120 hectares in Central Java and 277,760 hectares in East Java and 1,6 millions hectares of the rest outside Java (Kasryno, 1996). The five millions hectares of the remainder become a long term upland rice intensification program target areas (Fagi, 1995).

Comparing to lowland rice, the contribution of upland rice to national rice production is still low, although its potential is high. This means that the role of upland rice in Indonesian rice production becomes more important in the future. On the average, upland rice production in Indonesia is about 2.5 tons per hectare. The development rate is slow. In the last 25 years upland rice production increased only 45% i.e. from 1,622,000 tons to 2,345,000 tons; compared to lowland rice which increased 140% i.e. 24,666,000 tons (Anonymous, 1995).

Rice production could be increased through (1) intensification, (2) extensification and (3) cropping systems improvement programs (Prajitno, 1992). Intercropping is one of the forms of cropping patterns in cropping systems program, i.e. growing two or more crops simultaneously on the same field, in the same time, usually planted in rows side by side (Prajitno, 1987). Consequently there is an interaction between crops grown in this system. The crops should be chosen so they can get the advantages on using time and space efficiently and able to press down the competition effect to minimum (Prajitno, 1988).

Unlike lowland rice, upland rice which is grown in the dryland or rainfed areas, could be intercropped with other crops, annually or perennially. This paper limits the discussion on the interaction between upland rice with legume crops and horticultural crops, as a result of multi years field experiments in Upland Rice Research Institute, Faculty of Agriculture, Gadjah Mada University. Each experiment is usually used by the graduate students for their master thesis under the guidance of the author.

II. Theoretical framework

Interaction between two species can be studied with a "replacement series". A replacement series is the result of generating a range of mixtures by starting with a monoculture of one species and progressively replacing crop of that species with crop of the other species, until a monoculture of the latter is produced. The results of such an experiment are presented in a "replacement diagram", where for each species the yield per unit area is plotted against the proportion of the total number of seeds sowed. Competitive effects can be examined by the type of diagram illustrated in Figure 1.

In the figure, actual yields are given by solid lines and expected yields by broken lines. Expected yields are those that would be obtained if each species experienced the same degree of competition in mixture as in pure stand i.e. if interspecific competition is equal to intraspecific competition. Though this is unlikely in practice, this provides a useful basis for comparison. Three broad categories of interaction can be recognized. (1) The actual yield of each species is less than expected, which is called mutual inhibitation (figure 1a.). (2) The yield of each species is greater than expected. This can be termed mutual cooperation or complementation (figure 1b.). (3) One species yields less and the other more than expected. This can be termed compensation (figure 1c).

However since the physical units of the yield of each crop is not equal, for example ton/ha of upland rice vs ton/ha watermelon in intercropping is difficult to combine, de Wit (1960) proposed a physical unit to measure a combined yield of different species i.e. the relative yield :

$$\text{Relative Yield (RY)} = \frac{\text{Yield in intercropping}}{\text{Yield in monoculture}} \qquad (1)$$

The "Relative Yield Total" (RYT) of a two component intercropping system may be represented as follows :

$$RYT = \frac{Yab}{Yaa} + \frac{Yba}{Ybb} \qquad (2)$$

Where :

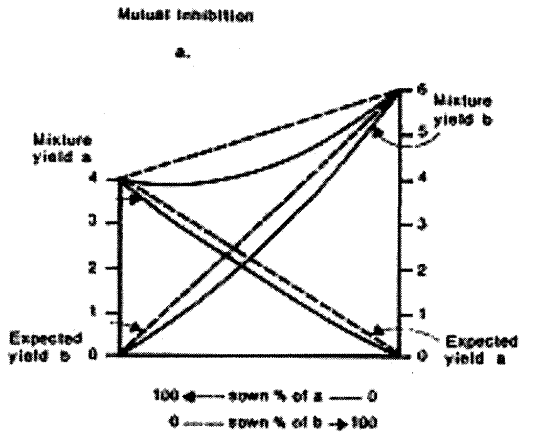
Yaa = yield of crop A as monoculture
Yab = yield of crop A as intercrop with crop B
Ybb = yield of crop B as mono culture
Yba = yield of crop B as intercrop with crop A

When the RYT is equal to or less than 1, there is no advantage to intercropping.

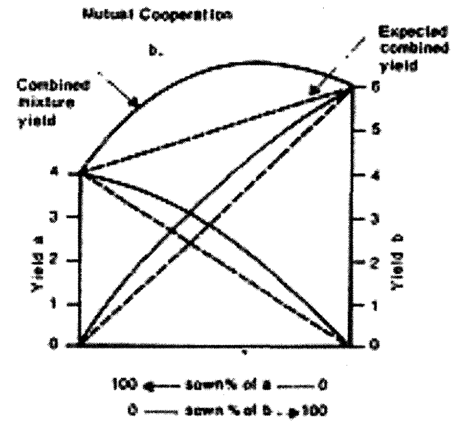
If we take into account the duration of the crop i.e. the time it occupies from planting to harvesting, we use the Area Time Equivalent Ratio (ATER) which was proposed by Hiebsch (1980) (*cit.* Ofori and Stern. 1987) :

$$ATER = \frac{RYa.\ ta + RYb.\ tb}{T} \qquad (3)$$

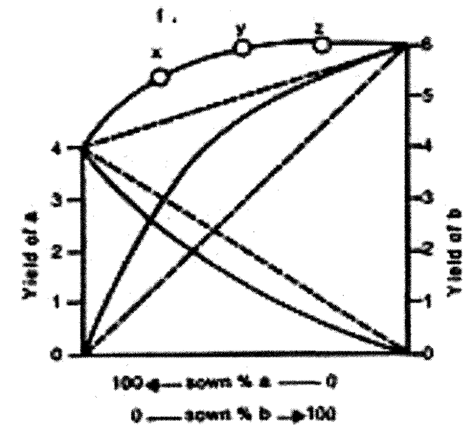
Where RYa and RYb are relative yield of crop A and B, ta and tb are the durations (days) for crop A and



a. Mutual Inhibitation



b. Mutual Cooperation



c. Compensation

Fig. 1. Types of inter-species interaction.

crop B, and T is the duration (days) of the whole intercrop system.

III. Some experimental results

As mentioned earlier, the experiments were conducted in Gadjah Mada Agricultural Experiment Station, Kalitirto, Yogyakarta. The altitude is about 146 m above sea level, with regosol soil type and C3 type of Oldeman agroclimatic classification. Yearly air temperature ranges from 27°C up to 35°C.

3.1. Interaction between upland rice and legumes

3.1.1. Upland rice vs velvet bean (*Mucuna pruriens.* L. DC.). (Kalis, 2001).

Weeds are one of the major problems in growing upland rice. The field experiment was aimed to study the effect of velvet bean on the growth and production of upland rice, and its associated weeds. The experiments was conducted in the wet season of 2000/ 2001. Two factors were considered, (1) upland rice varieties (Dodokan and Cirata), (2) proportion of upland rice: velvet bean, arranged in replacement series from 0% to 100% at 25% interval. Each plot size was 6x 4 m, giving 400 plants per plot under spacing of 30 x 20 cm. The design was 2 x 5 factorial arranged in split plot with upland rice varieties as main plot; with three replications.

The results of the experiment showed that the best upland rice yield was reached by the combination of 75% upland rice-25% velvet bean, i.e. 1.41 tons and 1.92 tons per hectare for dodokan and cirata varieties (table 1). It should be noted here, that the yield is relatively low, because dodokan and cirata are lowland rice which can be adapted to upland condition . The highest relative yield total (RYT) was reached by the proportion of 50% upland rice-50% velvet bean, i.e. 1.19 and 1.16 for dodokan and cirata respectively. The interaction of both crops belongs to the categories of mutual cooperation or complementary, as the RYT values of every mixture was above 1 (see figure

2.).

As an additional result the proportion of 25% upland rice and 75% velvet bean gave the greatest growth suppression of sedges, grasses and broad leaved weeds.

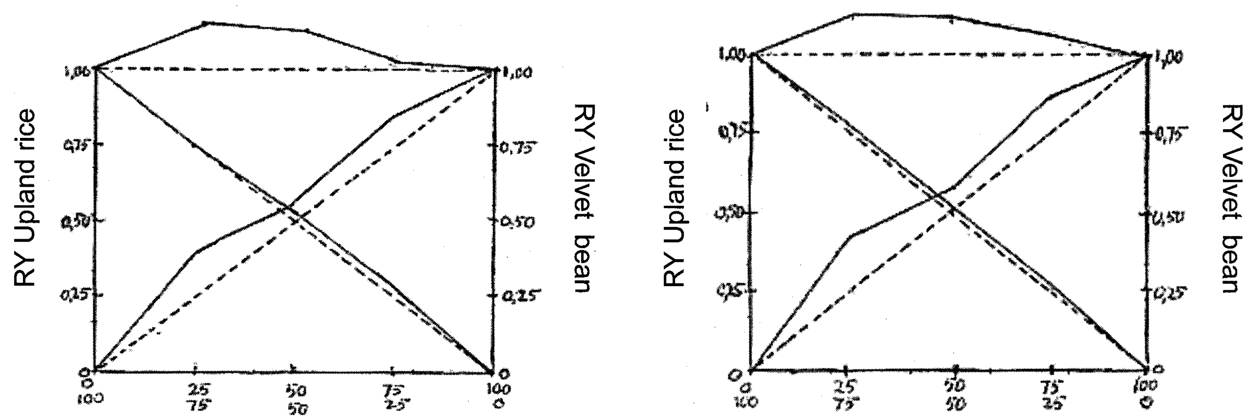
3.1.2. Upland rice vs mung bean (Nina, 2003).

The experiment was intended to find out the type of interaction exhibited when mung bean intercropped to upland rice at different planting time and population ratio. It was done during the wet season of 2002/2003. The design was 3 x 3 factorial of intercropping treatments with two augmented monoculture treatments arranged in randomized complete block design. The first factor was mung bean planting time, i.e. 10 days prior to upland rice (K1), at the same time (K2) and 10 days after planting upland rice (K3). The second factor was population ratio of mung bean to upland rice, i.e. 25%mung bean, 75% upland rice (P1), 50% mung bean, 50% upland rice (K2) and 75% mung bean, 25% upland rice (K3). Varieties used was Limboto for upland rice and Walet for mung bean.

The results revealed that combination of mung bean and upland rice in intercropping system led to an increase of upland rice yield but accompanied with a decrease of mung bean, thus a compensation type of interaction (figure 3). Mung bean planting time did

Table 1. Upland rice and velvet bean yields (ton/ha) in intercropping system and their relative yield (RY)

Proportion of Upland rive vs Velvet bean (%)	Yield		Relative Yield		RYT
	UR	VB	UR	VB	
Dodokan					
UR100	1.30	-	1.00	0.00	1.00
UR75VB100	1.06	2.29	0.81	0.27	1.08
UR50VB50	0.86	4.44	0.67	0.52	1.19
UR25VB75	0.62	6.36	0.47	0.35	1.22
VB100	-	8.49	0.00	1.00	1.00
Cirata					
UR100	1.73	-	1.00	0.00	1.00
UR75VB100	1.44	2.73	0.84	0.26	1.10
UR50VB50	1.04	5.77	0.64	0.56	1.16
UR25VB75	0.68	8.01	0.41	0.18	1.17
VB100	-	10.28	0.00	1.00	1.00



a. Dodokan b. Cirata

Fig. 2. Replacement diagram of upland rice-velvet bean intercropping

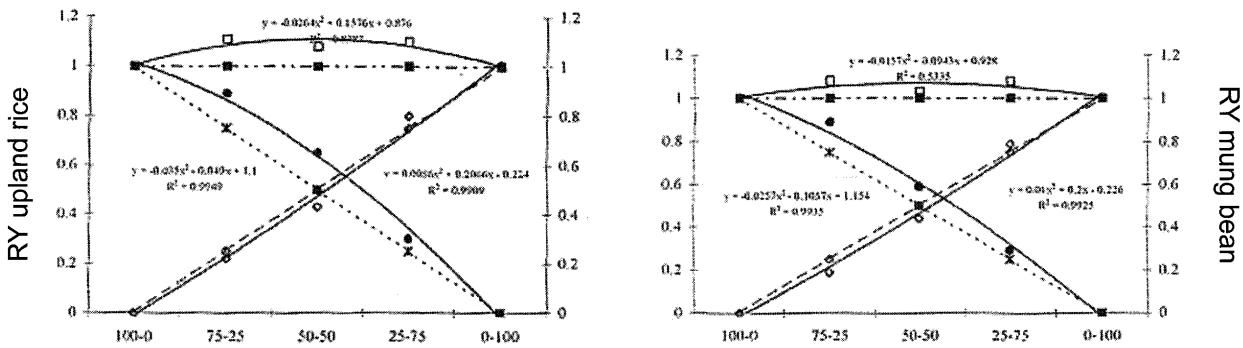
not give significant effect to the type of interaction.

The highest upland rice yield was reached by the 50% : 50% population ratio under the planting mung bean 10 days ahead of upland rice. However, the highest relative yield total (RYT) and area time equivalent ratio (ATER) was reached by the population ratio of 25% upland rice and 75% mung bean in the same planting time (table 2).

3.1.3. Upland rice vs groundnut (Hotnida, 2004).

The experiment was intended to find out the suitable varieties combination of upland rice and groundnut under intercropping system. It was done during the wet season 2003/2004. The design of the field experiment was 4 x 4 factorial arranged in strip plot with 4 additional monoculture treatments arranged in randomized complete block. The first factor was upland rice varieties, i.e. (1) Towuti, (2) Danaugaung, (3) Batulegi, (4) Limboto; while the second factor was groundnut varieties, i.e. (1) Singa, (2) Panter, (3) Komodo and (4) Kelinci. Crops were planted under population ratio of 50% : 50%.

The results revealed that combination of upland rice and groundnut varieties in intercropping system led to an increase of upland rice yield but accompanied by the decrease of groundnut yield, which means a compensation type of interaction. The most suitable varieties combination of this intercropping system was Towuti (upland rice) and Komodo (groundnut) i.e. it gave the highest RYT value (1.47) (table 4).



a. Mung bean planted 10 days before upland rice

b. Mung bean planted in the same time with upland rice

Fig. 3. Replacement diagram of upland rice-mung bean intercropping.

Table 2. Upland rice and mung bean yields (ton/ha) in intercropping system and their RYT and ATER

Treatment	Yield (ton/ha)		RYT	ATER
	UR	MB		
K1P1	4.92	1.45	1.10	1.11
K1P2	5.43	1.44	1.08	1.10
K1P3	4.91	1.80	1.10	1.15
K2P1	4.95	1.29	1.08	1.10
K2P2	4.94	1.48	1.03	1.04
K2P3	4.76	1.77	1.08	1.09
K3P1	4.90	1.38	1.04	1.09
K3P2	4.68	1.48	1.00	1.03
K3P3	4.69	1.76	1.07	1.08
MC	4.16	1.65	-	-

Note :

- Mung bean planted 10 days before upland rice (K1), together (K2), 10 days after (K3).
- P1 : 75% upland rice, 25% mung bean ; P2 : 50%, 50% ; P3 : 25%, 75%

However, the highest upland rice yield was reached by Danaugaung partnering with Komodo (groundnut) (table 4).

3.2. Interaction between upland rice and Horticultural Crops.

3.2.1. Upland rice vs watermelon (Tjahjono, 1995).

The field experiment had been carried out in the agricultural experiment station, Gadjah Mada University, Kalitirto, Yogyakarta, in the late dry season (August-December) 1994. The design was RCBD with six replacement series treatments with four replications, i.e. (1) watermelon monoculture (1:0), (2) 75% watermelon, 25% upland rice (3:1), (3) 50% watermelon, 50% upland rice in 1:1 rows arrangement (1:1), (4) 50%watermelon: 50% upland rice in 2:2 rows arrangement (2:2), (5) 25% watermelon, 75% upland rice (1:3) and (6) monoculture of upland rice (0:1).

The results of the experiment showed that upland rice, when intercropped with watermelon, was able to increase the watermelon yield 27% compared to its monoculture
(if the number of population is equal). On the other hand, watermelon was able to increase upland rice yield up to 28% (table 5). This means that complementation or mutual cooperation occurred in the intercropping of the two species (figure 4). Based on RYT value, the 1:1 rows arrangement is better than 2:2 although both gave positive effects. (table 5.). Cropping pattern 1:3 gave the highest RYT value (1.7). Only cropping pattern 3:1 gave the negative ef-

Table 3. Upland rice yield (ton/ha) under intercropping with groundnut

Upland Rice Varieties	Groundnut Varieties				Monoculture
	Singa	Panter	Komodo	Kelinci	
Towuti	2.10	2.64	4.00	2.60	3.23
Danau Gaung	2.22	2.57	4.45	3.18	3.56
Batu legi	3.99	3.27	3.31	3.26	4.79
Limboto	1.76	2.79	3.03	3.18	3.32

Table 4. Relative Yield Total values of intercropping between upland rice and groundnut

Upland Rice Varieties	Groundnut Varieties			
	Singa	Panter	Komodo	Kelinci
Towuti	1.11	1.04	1.47	0.96
Danau Gaung	1.13	1.13	1.23	1.15
Batu legi	1.15	1.35	1.01	1.13
Limboto	1.33	0.91	1.26	1.53

Table 5. Means of upland rice, watermelon yields (ton/ha) and their RYT value in intercropping system.

Treatment	Yield (ton/ha)		RYT
	Watermelon	Upland rice	
Watermelon monoculture	2.59	-	1.00
3 W : 1 UR	1.89	1.05	0.97
1 W : 1 UR	1.41	2.01	1.12
2 W : 2 UR	1.63	1.94	1.06
1 W : 3 UR	0.82	2.92	1.17
Upland rice monoculture	-	3.26	1.00

fect.

3.2.2. Upland rice vs onion (Lapanjang, 1997).

The experiment was carried out at our experiment station, Kalitirto, Yogyakarta, in the dry season 1996. 3 x 5 factorial treatments arranged in split plot with main plot arranged in latin square, was used with three replications. The main plot treatment was a mixed organic fertilizer, i.e. rice straw + EM4 ("mixed micro-organism" fertilizer) in three levels, i.e. (1) no organic fertilizer (A0), (2) rice straw + EM4 (A1) and (3) only EM4 (A2). The sub-plot consisted of replacement series treatments, i.e. (1) Onion monoculture (B0), (2) 75% onion, 25% upland rice (B1), (3) 50% onion, 50% upland rice (B2), (4). 25% onion, 75% upland rice (B3) and (5) upland rice monoculture (B4).

The results of the experiment showed that upland rice had beneficial effect from intercropping condition under additional organic fertilizer. On the contrary, onion had the beneficial effect from intercropping treatments if there was no additional organic fertilizer (figure 5.). The interaction type is compensation. The highest yield of upland rice was reached by the combination of 50% upland rice and 50% onion, but the highest RYT was reached by intercropping of 25% onion and 75% upland rice (table 6.).

3.2.3. Upland Rice vs Pineapple (Rahayu, 2004).

The aim of the research was to study (1) the effect of some pineapple varieties on the growth and yield of upland rice, (2) the best pineapple proportion in intercropping system which gave the highest yield of upland rice. The research was conducted on farmer's field during the wet season 2003/2004 at Logandeng village, Playen, Gunung Kidul district, Yogyakarta province. The design of the field experiment was 3 x 2 factorial + 3 additional treatments arranged in randomized complete block. The first factor was pineapple varieties i.e. Queen Blitar (Nb), Queen Hijau Bogor (Nq), and Cayenne Subang (Nc), while second factor was intercropping level i.e. pineapple monoculture (Po) and 50% proportion of intercropping system (P_{50}). The additional treatments consist of upland rice monoculture (P_{100}), intercropping with proportion Queen Blitar 25% : 75% upland rice (P_{75}) and intercropping with proportion Queen Blitar 75% : 25% upland rice (P_{25}). The rice variety used was IR-64.

The results of this research showed upland rice-some varieties of pineapple gave beneficial effect to upland rice (increased upland rice yield). Intercropping of 75% Queen Blitar, 25% upland rice gave the highest yield of grain per hill. The upland rice and Cayenne type of pineapple under 50% proportion gave higher yield per hectare compared to upland rice-Queen type of pineapple intercropping (table 7).

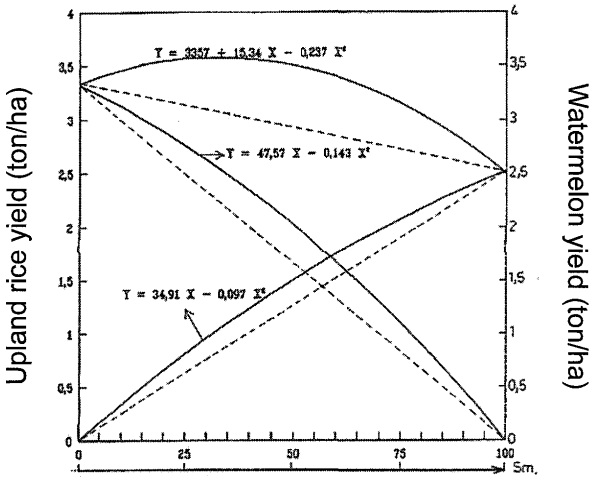


Fig. 4. Replacement series diagram of upland rice-watermelon intercropping system.

Table 6. Means of upland rice and onion yields (ton/ha) and their RYT in intercropping system.

Treatment	Yield (ton/ha)		RYT
	Onion	Upland rice	
Onion monoculture	3.56	-	1.00
75% O : 25% UR	2.57	1.01	1.04
50% O : 50% UR	1.91	2.01	1.12
25% O : 75% UR	1.19	2.87	1.17
Upland rice monoculture	-	3.70	1.00

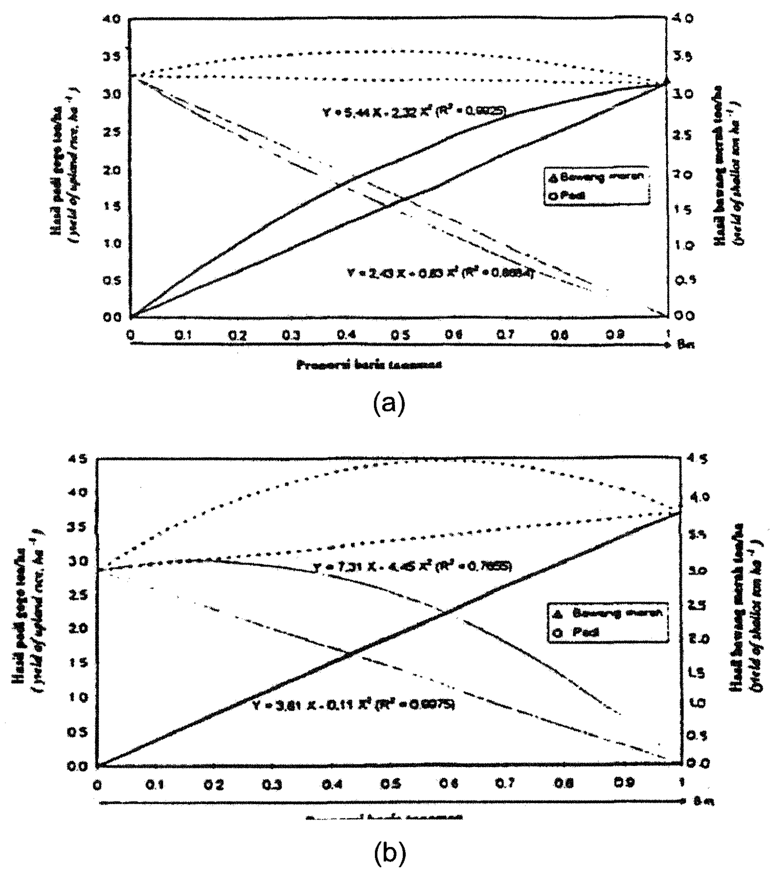


Fig. 5. Replacement series diagram of upland rice-onion intercropping system.
(a). no organic fertilizer. (b). with organic fertilizer.

Table 7. The effect of intercropping level on the yield of upland rice (ton/ha) and the weight of pineapple biomass (g. dry weight/plant).

Treatment	Upland rice	Pineapple
P100	4.24	-
NB25 P75	2.28	29.34
NB50 P50	2.18	50.47
NB25 P75	1.47	33.16
NQ50 P50	2.37	37.15
NC50 P50	2.45	49.69
NB100	-	24.97
NQ100	-	35.26
NC100	-	88.06

It should be noted here that the pineapple still under was vegetative phase when upland rice was harvested.

The descrease in soil characteristics (CEC and N total) under intercropping system was lower compared to upland rice monoculture. Upland rice-pineapple intercropping increased soil bulk density and pore volume. The highest soil nitrogen absorption was met in upland rice monoculture.

IV. Conclusions

One of the advantages of upland rice compared to lowland rice is that it can be grown with other crops in intercropping system. Unfortunately, in Indonesia, the production potential of upland rice is still lower compared to lowland rice, although area suitable for developing this crop is much more broader. Consequently, breeding programs for high yield varieties of upland rice is urgent and should be done continuously.

The types of interaction between upland rice and other crops are specific, depend on crop species grown side by side in intercropping system. From the compilation of six field experiments, the results showed that most legume crops stimulate upland rice yield. However, the effect of upland rice on legume crops is different, i.e. decreasing yield such as in mung bean and groundnut and no significant effect such as in velvet bean. Thus a compensation type of interaction is occurred.

There is no general rule for interaction with horticultural crops. Complementary type was shown in the interaction between upland rice and watermelon. However, compensation type of interaction occurred on the intercropping between upland rice and pineapple, where upland rice got the beneficial effect. Compensation type was also shown on the interaction between upland rice and onion, but the beneficial effect was received by onion. However, under the occurrence of organic fertilizer, upland rice got the beneficial effect.

References

Anonimous. (1995) Upland Rice Culture. Department of Agriculture. Republic of Indonesia. Jakarta. (in Indonesian).

Fagi, A. M. (1995) Strategies for Improving Rainfall Lowland Rice Production System in Central Java. *In* K.T. Ingram. Rainfall Lowland Rice. Agricultural Research for High Risk Environment. IRRI. Los Banos. pp. 189-199.

Hotnida, S. K. (2003) Studies on The Growth and Yield of Upland Rice and Groundnut Intercropping System. Master thesis. Faculty of Agriculture. Gadjah Mada University. Yogyakarta. pp. 106 (unpublished).

Kalis, A.V. (2001) Studies on The Intercropping Between Upland Rice and Velvet Bean (*Mucuna pruriens* L. DC.) and Its Effect on The Growth of Associated Weeds. Master thesis. Faculty of Agriculture, Gadjah Mada University. Yogyakarta. pp. 142. (unpublished).

Karama, A. S. (2000) Agriculture development in Indonesia. Proc, National Seminar on Land Resources. Bogor, Dec. 6-8, 1999. pp. 20-31. (in Indonesian).

Kasryno, F. (1996) Indonesia rice economy, perspective toward year 2010. Proc. The First Asia International Rice Conference. Singapore Oct. 24-25, 1996.

Lapanjang, I. M. (1997) The Effect of Organic Fertilizer on Upland Rice-Onion Intercropping System. Master thesis. Faculty of Agriculture, Gadjah Mada University. Yogyakarta. pp. 138 (unpublished).

Muhtadi (1999) The decline of Indonesian agriculture. Kompas Nov. 11, 1999. (In Indonesian).

Nina, A. (2003) Studies on Planting Time and Row Numbers of Mungbean Intercroppedwith Upland Rice. Master thesis. Faculty of Agriculture, Gadjah Mada University. Yogyakarta. pp. 82. (unpublished).

Ofori, F. and W. R. Stern (1987) Cereal-legume intercropping systems. Adv. Agron. 41: 41-90.

Prajitno, D. (1987) Advantage and disadvantage of intercropping system. A system approach. Proc. 3rd National Press Seminar. Yogyakarta Sept. 25, 1986. pp. 25-41. (in Indonesian).

Prajitno, D. (1988) Crops production technology in marginal land. Paper presented at Panel Discussion of Indonesian Agronomic Society. Bogor. pp. 35. (in Indonesian).

Prajitno, D. (1992) Optimization of Cropping Systems in Progo River Basin Area. Dissertation (Dr. in Agric. Sci.). Gadjah Mada University. Yogyakarta. pp. 431 (unpublished).

Rahayu, M. (2004) Growth and Yield of Upland Rice in Intercropping With Some Varieties of Pineapple. Master thesis. Faculty of Agriculture, Gadjah Mada University. Yogyakarta. pp. 169. (unpublished).

Suryana, A. (2000) Positioning agriculture development as a center for national development. Proc. National Seminar on Land Resources. Bogor, Dec. 6-8, 1999. pp. 35-54. (in Indonesian).

Tjahjono, B. (1995) Cropping Patterns Studies in Upland Rice-Watermelon Intercropping System. Master thesis. Faculty of Agriculture, Gadjah Mada University. Yogyakarta. pp. 117 (unpublished).