Effect of Biodiversity to Control Diseases and Insect Harms of Vegetables in Organic Farming in the Tropics

SUGIYAMA Shintaro[1], SINTH Sarobol[2] and
TAWAN Hangsoongnern[3]

[1] Director, Rainbow Farm, Station for Study and Education of Tropical Organic Farming
Professor Emeritus of Keisen College of Horticulture
[2] Professor and Coordinator, Thailand Research Fund, Regional Office, Thailand
[3] Managing Secretary, Rainbow Farm, Thailand

Preface

In 1986, when S. Sugiyama visited an organic coffee farm in Mindanao, Philippines, where coffee was mix-planted with 6 fruit trees of banana, papaya, mango, tamarind, coconut and ipiru-ipiru (leguminous tree for soil fertility), he was surprised, there were very few trace of diseases and harmful insects, even in the tropics of high temperature and high humidity. He thought that, here should be many kinds of organisms of biodiversity, which would stop one or two pathogen or harmful insect to develop predominantly to become agricultural pests. This thought became a hypothesis during his studies on organic farming in the tropics.

Table 1. Temperatures and rainfalls comparing between Chiang Mai and Tokyo

		Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Year
Temp. (℃)	Tokyo	5.2	5.6	8.5	14.1	18.6	21.7	25.2	27.1	23.2	17.6	12.6	7.9	15.6
	Ch. M.	21.4	23.6	26.5	28.9	28.7	28.0	27.7	27.3	27.2	26.5	24.4	21.7	26.0
Rain (mm)	Tokyo	45	60	100	125	138	185	126	148	180	164	89	46	1406
	Ch. M.	8	3	12	50	161	132	160	234	228	122	58	18	1186

In May of 1997 he went to Chiang Mai, Thailand, and visited an organic farm, which changed to organic one a few years ago, according to the farmer's damage of health by agricultural drugs. The farmer mix-planted here 43 kinds of plants of vegetables, fruit trees, bamboos and herbs, and there looked no harms of disease and insect. He and his wife worked only to harvest the fruits of agriculture, as if they were Adam and Eve in the garden of Eden. We wanted to study mix-planting with vegetables, at the village of Donpao, west of Chiang Mai city, borrowing an area from Mr. Sorasak Mata, who had interest on organic farming, because this area was a center of onion production after crop of rice with much chemical drugs, which let him wish to help our study on organic farming.

Materials and methods of the experiment

The area was about 1 rai (1600 m^2), in the midst of paddy field and surrounded triple by canal, trees and banana plants (Fig. 1). The area was piled up with gravel soil of 40cm height for fear of flood. As a pretest we seeded there Japanese pumpkin (*Cucurbita maxima*) on earth, and rape and cabbage in a net house in early July. But growth of them were not well by harms of insect for pumpkin by cucumberbeetle, for rape by cabbageworm and for cabbage cabbagesawfly (*Athalia rosae*) and also by bad gravel soil of high acidity. Mr. Sorasak improved the soil by mounding with better paddy soil from digging pond side of the area.

The experiment started in early November. We made there 27 planting beds of 1 m × 18 m with compost ("bokashi") of 3-4 kg/m^2. Bokashi was made as following; 4 (volume) of dried chicken dung, 3 of sifted soil, 2 of rice husk and 1 of rice bran were mixed adding water, and after 1-2 days with starting to heat turned over once a day, continued for 1 week, completed with end of the fermentation.

The seasons of the crop were; winter season from around November to February, summer season from

March to May and rainy season from June to October. For winter seasons we planted seedlings of two kinds of *Solanaceous* plants on two halbs of one planting bed, and also for *Cucurbitaceous* and *Leguminous* vegetables we planted samely with three repetitions (Table 2). But for summer and rainy seasons we planted vegetables adapted to grow under hot and rainy weathers. Sometimes when it was difficult to keep the order of planting, because of overgrew of vegetables to next season, or by short of seedlings, we changed the order. Rate of harms by disease and insects was counted with the grade of harms as following, cannot sell in the market=1, partly difficult to sell=0.5, and about well for selling=0. The average rate of harms for a season was counted as total value of the grade of harms was divided by number of vegetable beds of the season. The average number of rate of harms for winter season was reliable, because there 3 kinds of plant families were put in about uniformly.

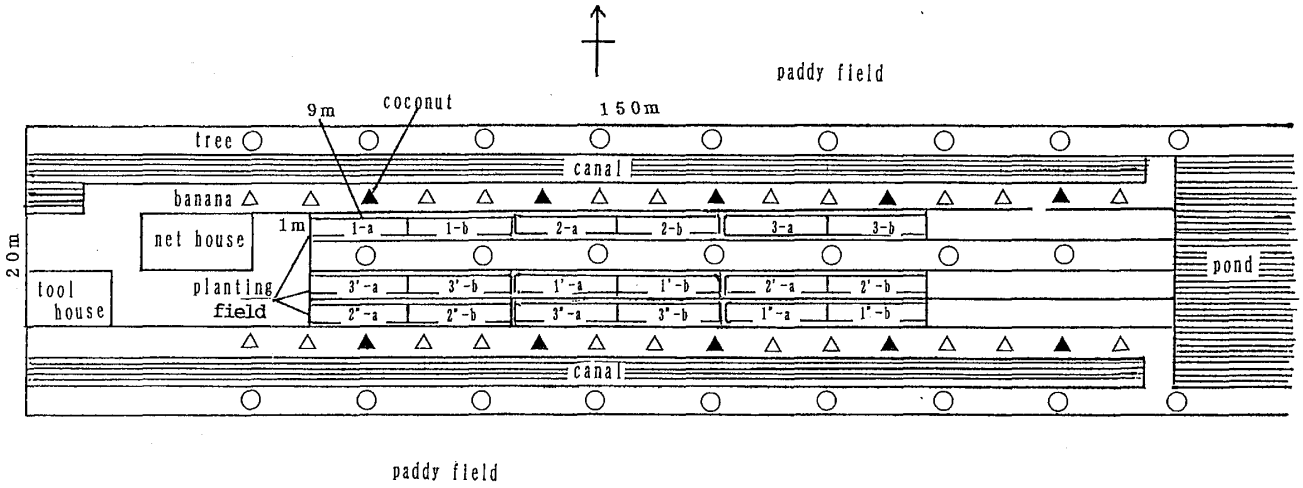

Fig. 1 Scenes around the experimental farm in Donpao Village

Results of the experiment (Table 2, and Fig. 2)

In winter season of 1997, in the young growth vegetables was not so bad, but in after, eggplant and tomato were attacked by insect of fruit borer, and cucumber by cucumber beetle severely. Sugarpea was infected by bacterial blight, and okura by unknown disease infected. Yardlongbeen was attacked by aphid, red pepper was infected by *Phytophthora* rot intermediately. The average rate of the harms by pests of this winter season was 89 %. In summer season of 1998, one bed of egg plant overstayed from the last season, and lettuce, coliander, shallot, cerely and cabbage were entered into the beds of fruit vegetables. The average rate of harms of the season was 45 %, a little dropped. In rainy season followed, eggplant, wingedbean, lettus and yardlongbean grew rather better. It was interesting, Chinese cabbage had no pest harms in spite of its weakness for them. Average rate of harms was 36 %, a little lower than expected by the effect of mix-planting.

In winter season of 1998, cucumber, yardlongbean, tomato and eggplant were improved comparing with the results of the last winter season, average rate of harms being 31 %. In summer season of 1999, vegetables adaptable to high temperature were increased, and average rate of harms dropped to 11 %. In rainy season of this year, rate of harms dropped to 8 %, and in the winter season it was 6 % finally. The last data of 6 % was gained from a disease of sugarpea by Bacterial blight.

From these results, when we make a figure plotting the average rate of harms in winter seasons of reliable data as Fig. 2, it comes down from 89 % of winter season, 1997 to 6 % of winter season, 2000. In this line when it attained to about 20 % of the starting rate 89 %, i.e. 18 %, it is ascertained as a kind of safety line (Fig. 2), effective point of mix-planting to control the harms of pests, the time of this point is estimated to be about August of 1999, being about 1.5 years later from the start of the experiment (result of the first crop was taken at 1.5 years before the

point on the line).

Table 2.　Results of vegetable growing at the field in Donpao Village (1997～99)

Year and season		Disposition of the rows[2] 1a	1b	2a	2b	3a	3b	Rate of[4] harms(%)
1997	R[1]	(preliminary test)	×[3] kale	×komatsuna	×Japanese pumpkin(Cucurbita maxima)			100
	W	×eggplant	△redpepper	×cucumber	×cucumber	×sugarpea	×okura	
		×okra	△yardlong bean	×sugarpea	△yardlong b.	×tomato	×eggplant	
		△yardlong b.	×sugarpea	×eggplant	×tomato	×cucumber	×cucumber	89
1998	S	×eggplant	○shallot △chingensai	△lettuce	○coriander	△cabbage	○celerey	
		△red pepper	×tomato	×bittergourd	×loofer	○basella	×okra	
		○coriander	△cabbage	○celerey	△chingensai	△lettuce	○shallot	45
	R	△okra	○wingedbean	○lettuce	○onion ○eggplant	△cucumber	○chinese cabbage ○onion	
		△redpepper	△tomato	×bittergourd	×loofer	△yardlong b.	△green eggpl.	
		△eggplant	△loofer	△eggplant	○yardlong b.	-	-	36
	W	△cucumber	○winged bean	×sugar pea	○yardlong b.	○tomato	○eggplant	
		×sugar pea	○yardlong b.	○tomato	○redpepper	△cucumber	×bittergourd	
		○eggplant	○tomato	△cucumber	○loofer	×sugarpea	○yardlong b.	31
1999	S	○tomato	○winged bean	△loofer	○yardlong b.	○tomato	○red pepper	
		△loofer	○yardlong b.	○yardlong b.	○red pepper	○okra	○basella	
		○egg plant	○green eggpl.	△cucumber ○komatsuna	△loofer	○pakbun	○pakbun	11
	R	○yardlong b.	○wingedbean	○red pepper	△tomato	○loofer	△bittergourd	
		○eggplant	○red pepper	○loofer	△bittergourd	○yardlong b.	○wingedbean	
		○eggplant	○moroheiya	○yardlong b.	○okra	○eggplant	○red pepper	8
	W	○loofer	○cucumber	○yardlong b.	△sugarpea	○tomato	○eggplant	
		○yardlong b.	○okra	○red pepper	○tomato	○bittergourd	○cucumber	
		○eggplant	○tomato	○loofer	○cucumber	○okra	△sugarpea	6

1)Season means S:summer-,R:rainy- and W:winter seasons. 2)Disposition of rows 1,2 and 3: from west to east of 18m rows, and "a" is west half,and" b" is east half. 3)Harms by diseases and insects, ×: severe, △:middle and ○:about normal. 4)Rate of harms was the mean value calculated by ×=100, △=50 and ○=0% on harms by insects and diseases classified through the appearance.

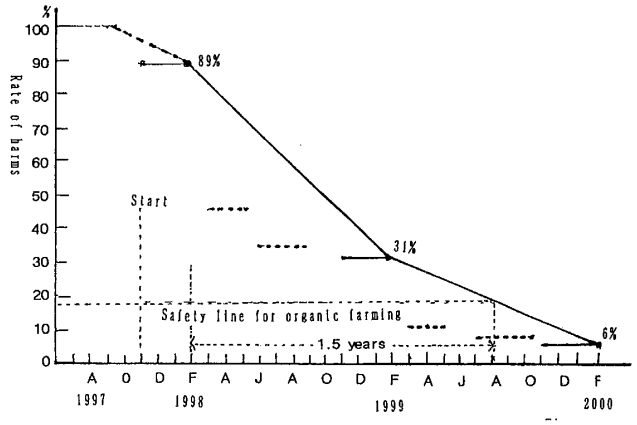

Fig. 2 Change of rate of harms of the pests with time

Fig. 3 Cucumber (left) and tomato (right), which did almost not receive the pest harms after one year of the start of organic farming.

Discussion

From the results of our experiment, by the repeated 7 times mix-planting of vegetables during 2 years, average rates of harms of agricultural pests decreased from the start of 89 % to the final data of 6 %. By this experiment we will ascertain that the environment of mix-planting, where effects of biodiversity of many kinds of organisms above and under ground are expected, could control the activities of diseases and harmful insects clearly. On such clear depression of rate of harms for only 2 years, we can suspect any effects of a suitable environment of experimental farm of surrounding water of canal and ample woods. But the main effects of it must be attributed to the environment of biodiversity which was made by the repeated mix-planting of vegetables, under the suitable natural condition.

We could estimate by the line of average rates of pest harms, the clear depression of the rate of harms to 18 % (Fig.2), came after 1.5 years later from the start. On the 1.5 years for the depression of the rate of harms to 20 % of the first 89 %, we can understand about well, because when we visited an organic farm of YMCA in Chiang Mai in August of 1997, being estimated after less than 2 years from the open of the farm, environment of the farm looked nearly completed to control pests by mix-planting of many kinds of vegetables under woods. Length of the time to get the stable condition were not so much far between both cultures. Now Sugiyama has an experience that, at Isehara near from Tokyo, where he had continued organic farming of vegetables, it was just 3 years later of the start, when an natural enemy, "nanahoshi tentoh", seven-spotted lady-bird, much propagated, accordingly insect harms decreased and environment of the farm was set well for organic farming. And many organic farmers around the center of Japan are used to say, "when you start organic farming, you must wait at least 3 years until pests of farms decrease and the environment becomes stable". Comparing the environments between Chiang Mai and Tokyo, the year temperature about 26 ℃ in Chiang Mai and 16 ℃ in Tokyo (Table 1), the difference being 10 ℃. From the difference of 10 ℃, we can induce a simple formula of Q_{10}= 2 (Sakamura, 1952), which means that, when temperature is 10 ℃ higher, biological activity becomes about twice. It will be truth that, when in Tokyo it takes 3 years to get stable environment of low pest harms by organic farming, it will take in Chiang Mai with temperature of 10 ℃ higher 1.5 years to get the same results for getting the stable environment by the effect of biodiversity. We have another evidence of Q_{10}=2 by our experience of making bokashi that, in Japan it takes 2 weeks by fermentation, but in Chiang Mai we can make bokashi with the same method through only 1 week. By this result, we can also estimate that, even in Japan, belonging to temperate area, the stable environment of organic faming should be conformed by the effect of biodiversity samely to the tropics.

On the effect of mix-planting to control insect harms Andow (1991) reported by 287 cases of experiments which could compare results between mix-planting and simple planting. In it, by mix-planting harmful insect decreased in 52 % of the cases, and

increased in 15 %. And for natural enemies compared by 130 cases, it increased in 53 % and decreased in 9 % of the cases. Then for insects, the mix-planting has a clear tendency to decrease harmful insect and to increase insects of natural enemy. And Nakasuji (1997) introduced 5 reports (including Andow, 1991) of the same results that by mix-planting harmful insects decreased and insects of natural enemies increased.

For disease Zhu et al (2000) reported an experiment of big scale for 2 years in Yunnan, China, on the mix-planting of rice varieties of glutinous (susceptible to rice blast) of 4 lines and non- glutinous (resistant) of 1 line. As the results, rice blast decreased 2-3 % in the line of glutinous rice of mix-planted area comparing to the control plot, and in non-glutinous lines it decreased 50 % than the control. This experiment was cooperated by Chinese and American scientists and reported by "Nature" (for searching of this report Sugiyama owes much to the kind help of Dr. Kohiti Fujimoto).

Yasuda (1994) also reported a result of organic farming for 30 years at Hikami County, Kyoto, and refered that harms by diseases and insects decreased by the effects of mix-planting of many kinds of crops on small areas by hand cultivations continued.

In our experiment, why harms of insects decreased earlier than that of diseases by the effects of biodiversity? The answer may be that harmful insects decreased by a simple process of eating by the conquerer; On the other hand, diseases decreased mainly through the complicated process of immunology such as infection and getting ill with related hosts and other organisms. Effects of biodiversity on depression of pest harms looked more in rainy season than in dry season, may be because of activation of the biodiversity through the condition of solution or high humidity.

And then, we have another question that, the environment of biodiversity to control pest harms will proceed or evolve with time? For this question Dr. Motoo Kimura, molecular-evolutionalist says that, "in a certain area a population of individuals which are variable in structure and activity, can have higher fitness to live than that of uniform characters. And species which has ability to generate more variants can get more in the competition to other species" (Kimura, 1988). This words are about the same to that of C. Darwin's "Origin of Species" (1859). Then, for the environment controlling agricultural pest by biodiversity, we can say that, it will proceed or evolve with time as well as supply of water and nutritions is kept. In practice, organic farmers are seldom to stop his farming, whenever he had succeeded once to control agricultural pests by the effects of biodiversity.

In conclusion we can say as following;

1. In organic farming an environment conformed by the biodiversity of organisms above and under ground can control agricultural pests (diseases and harmful insects).
2. The effect of biodiversity to control agricultural pests is rapid in the tropical area, and slow in the temperate area, following the formula $Q_{10} = 2$. When temperature 10 ℃ higher, rapidness of the effects become twice.
3. These effects of biodiversity to control insect harms appeared earlier than that to control diseases. When it is rainy season, the effects of controlling pests looked higher than in dry season.
4. This effect of the biodiversity looked to control agricultural pests was thought to proceed (or evolve) with time, whenever the supply of organic fertilizers and water is complete.

Literatures Cited

Andow, D. A. 1991. Vegetational diversity and arthropod population response. Ann. Rev. Entomol. 36, 561-586.

Darwin C. 1959. On the origin of Species by Means of Natural Selection. (translated by R. Yasugi, as "Shu no Kigen" 1971, Iwanami Book Co. (Japanese).

Kimura, M. 1988. Thoughts on Evolution of Organisms. Iwanami Book Co. (Japanese).

Nakasuji, F. 1997. Studies on Integrated Pest Management. Yokendo Book Co. (Japanese).

Sakamura, T. 1952. Plant Physiology, Band 1, 12-15, Band 2, 62-63. Shokabo Book Co. (Japanese).

Scientific Periodical Data, 1999. Maruzen Book Co. (Japanese).

Sugiyama, S., Sinth S., and Tawan H. 2000. Organic

farming depending on the biodiversity in the tropics. Agric. Extens. Journ, Chiang Mai University 3, 3, 22-32(Thai).

Sugiyama, S., Sinth S., and Tawan H. 2002. Organic agriculture in the tropical area by means of biodiversity. San-Ai Education Study Report 11, 1-7. San-Ai Education Foundation (Japanese).

Yasuda, S. 1994. Attainments of Organic Farming in Japan, Space Yui Book Shop (Japanese).

Zhu, Y, et al. 2000. Genetic diversity and disease control in rice. Nature 406, 718-722.

熱帯の野菜有機栽培における生物多様性の病虫害抑制効果

杉山信太郎・Tawan H. ・Sinth S.

摘　要

フィリピンやタイでの作物や果樹の混植栽培で，病虫害が予想以上に抑制される現象に着目し，タイ国チェンマイ市郊外の堀割りや木立ちに囲まれた水田跡地に，各小面積に植えた野菜数種類を混作する栽培を年間3作，2年間継続して，病虫害をこみにした被害率が89%から2年後に6%に低下する事実を認めた．被害率が最初の20%まで低下した期間は1.5年（18カ月）で，これが東京付近で経験的に自他ともに認められる病虫害が減少する3年間の1／2であること，また年間平均気温がチェンマイで26℃，東京で16℃で温度差の10℃から，$Q_{10}=2$の温度反応式を満たすことを認め，有機農業の継続栽培による病虫害の減少が，地上・地下の多様な生物の集団の抑制作用によることを推定した．また，混作の継続により虫害が病害より早く減少し，雨期に乾期より病虫害が低下することを観察した．さらに生物多様性の進化の理論から，有機農業における生物多様性による病虫害抑制作用は養・水分が補給される限り，時間的に進行することを理解した．