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

SUGIYAMA Shintaro¹, SINTH Sarobol² and TAWAN Hangsoongnern³

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.

Materials and methods of the experiment

The area was about 1 rai (1600 m²), 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/m². 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

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

| Temp. Tokyo | 52 | 56 | 85 | 141 | 186 | 217 | 25.2 | 27.1 | 23.2 | 17.6 | 12.6 | 7.9 | 15.6 |
| C | 21.4 | 23.6 | 26.5 | 28.9 | 28.7 | 28.0 | 27.7 | 27.2 | 26.5 | 24.4 | 21.7 | 20.0 |

| Rain Tokyo | 45 | 60 | 100 | 125 | 138 | 185 | 136 | 148 | 180 | 154 | 89 | 46 | 1406 |
| mm | 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.
March to May and rainy season from June to October. For winter seasons we planted seedlings of two kinds of Solanaceous plants on two halves 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 overcrowd 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.

![Diagram of farm layout](image)

**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. Sugarapea was infected by bacterial blight, and okura by unknown disease infected. Yardlongbean 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 sugarapea 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
Table 2. Results of vegetable growing at the field in Donpao Village (1997 – 99)

<table>
<thead>
<tr>
<th>Year and season</th>
<th>Disposition of the rows</th>
<th>Rate of harms(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1997 R&lt;sup&gt;1&lt;/sup&gt; (preliminary test)</td>
<td>X&lt;sup&gt;2&lt;/sup&gt; kale X komatsuna X Japanese pumpkin (Cucurbita maxima)</td>
<td>100</td>
</tr>
<tr>
<td>W</td>
<td>x eggplant △ red pepper x cucumber x cucumber x sugar pea x okura</td>
<td></td>
</tr>
<tr>
<td></td>
<td>x okra △ yardlong bean x sugar pea △ yardlong b. x tomato x eggplant</td>
<td></td>
</tr>
<tr>
<td></td>
<td>△ yardlong b. x sugar pea x eggplant x tomato x cucumber x cucumber</td>
<td>89</td>
</tr>
<tr>
<td>1998 S</td>
<td>x eggplant △ chingensai △ lettuce △ coriander △ cabbage △ celery</td>
<td></td>
</tr>
<tr>
<td></td>
<td>△ red pepper x tomato x bittergourd x loofer △ basella x okra</td>
<td></td>
</tr>
<tr>
<td></td>
<td>△ coriander △ cabbage △ celery △ chingensai △ lettuce △ shallot</td>
<td>45</td>
</tr>
<tr>
<td>R</td>
<td>△ okra △ winged bean △ lettuce △ onion △ eggplant △ cucumber △ onion</td>
<td></td>
</tr>
<tr>
<td></td>
<td>△ red pepper △ tomato x bittergourd x loofer △ yardlong b. △ green eggpl.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>△ eggplant △ loofer △ eggplant △ yardlong b. △ - △ -</td>
<td>36</td>
</tr>
<tr>
<td>W</td>
<td>△ cucumber △ winged bean x sugar pea △ yardlong b. △ tomato △ eggplant</td>
<td></td>
</tr>
<tr>
<td></td>
<td>x sugar pea △ yardlong b. △ tomato △ red pepper △ cucumber △ bittergourd</td>
<td></td>
</tr>
<tr>
<td></td>
<td>△ eggplant △ tomato △ cucumber △ loofer x sugar pea △ yardlong b. △</td>
<td>31</td>
</tr>
<tr>
<td>1999 S</td>
<td>△ tomato △ winged bean △ loofer △ yardlong b. △ tomato △ red pepper</td>
<td></td>
</tr>
<tr>
<td>△ loofer △ yardlong b. △ yardlong b. △ red pepper △ okra △ basella</td>
<td></td>
<td></td>
</tr>
<tr>
<td>△ egg plant △ green eggpl △ cucumber △ loofer △ pakbun △ pakbun</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>R</td>
<td>△ yardlong b. △ winged bean △ red pepper △ tomato △ loofer △ bittergourd</td>
<td></td>
</tr>
<tr>
<td>△ eggplant △ red pepper △ loofer △ bittergourd △ yardlong b. △ winged bean</td>
<td></td>
<td></td>
</tr>
<tr>
<td>△ eggplant △ moroheiya △ yardlong b. △ okra △ eggplant △ red pepper</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>W</td>
<td>△ loofer △ cucumber △ yardlong b. △ sugar pea △ tomato △ eggplant</td>
<td></td>
</tr>
<tr>
<td>△ yardlong b. △ okra △ red pepper △ tomato △ bittergourd △ cucumber</td>
<td></td>
<td></td>
</tr>
<tr>
<td>△ eggplant △ tomato △ loofer △ cucumber △ okra △ sugar pea</td>
<td>6</td>
<td></td>
</tr>
</tbody>
</table>

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, X: severe, △: middle and O: about normal. 4) Rate of harms was the mean value calculated by X = 100, △ = 50 and O = 0% on harms by insects and diseases classified through the appearance.
to 18% (Fig. 2), came after 1.5 years later from the start. On the L5 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°C in Chiang Mai and 16°C in Tokyo (Table 1), the difference being 10°C. From the difference of 10°C, we can induce a simple formula of \( Q_{10} = 2 \) (Sakamura, 1952), which means that, when temperature is 10°C 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°C 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 farming should be conformed by the effect of biodiversity namely 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 23% 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-evolutionist 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 nutrition 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 $Q_{10}/\Delta T = 2$. When temperature 10°C 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
farming depending on the biodiversity in the
tropics. Agric. Extens. Journ, Chiang Mai Uni-
versity 3, 3, 22-32 (Thai).
agriculture in the tropical area by means of
biodiversity. San-Ai Education Study Report
in Japan, Space Yui Book Shop (Japanese).
Zhu, Y. et al. 2000. Genetic diversity and disease

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塩水に木立に囲まれた水
田跡地に、各小面積に植えられ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
15年（18ヶ月）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、Q10 = 2の温
度反応式を満たすことを認めた、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って推定した。また、混作
の継続により虫害が病害より早く減少し、定期に乾
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防止作用は養・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。