TECHNOLOGY FOR SUSTAINABLE AGRICULTURE IN TAIWAN

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SUSTAINABLE AGRICULTURE IN TAIWAN

Excessive use of chemical fertilizers and pesticides in modern agriculture has caused environmental pollution in Taiwan, while at the same time self-sufficiency in food has decreased. The sustainability of agriculture has become a major issue. According to Lockeretze (1985), sustainable agriculture is a loosely defined term that encompasses a range of strategies for addressing a number of problems, including loss of soil productivity from erosion and related nutrient losses, surface and ground water pollution from pesticides and fertilizers, and low farm incomes as a result of reduced commodity prices and high production costs.

USE OF ORGANIC MATTER FOR SUSTAINABLE AGRICULTURE IN TAIWAN

Source and Application Rates of Organic Manure

The source of organic materials in Taiwan may be classified into the following categories: crop residues, green manure, common compost, mushroom compost, cattle manure, swine manure, poultry manure, municipal refuse, wastes left after oil extraction, and residues from processing animal products (Hsieh and Hsieh 1989). Organic materials should be composted before they are applied to the soil. A suitable method of composting is described in Hsieh and Hsieh (1990).

Since the nutrient content of organic manures varies greatly according to the type of organic material, while the nutrient requirements of different crops also vary, the selection of organic manures should meet the requirements of the particular crop. Generally, leafy vegetables require more nitrogen for better vegetative growth, while fruit trees and fruiting vegetables require less nitrogen and more phosphorus and potassium for better flowering.

Crop Yield and Quality in Organic Farming

Experiments were carried out to compare yield performance of conventional (chemical) farming with organic farming. An intermediate system (mixed chemical and organic fertilizers) was also used. The high- quality rice variety Taichung 189 was planted at a spacing of 25cm x 21cm with the following scheme of fertilization:

1. *Conventional farming*: Chemical fertilizer at a rate of $N\text{-}P_2O_5\text{-}K_2O$: 160-6—60 kg/ha.
2. *Intermediate type of farming*: One half each of chemical fertilizer and organic compost. The latter was applied as a basic fertilizer.
3. *Organic farming (A)*: Hog manure compost (13.3 mt/ha) alone, applied as a basic fertilizer. *Organic farming (B)*: Chicken manure compost (6.6 mt/ha) alone, applied as a basic fertilizer. Only natural pesticides were used for pest control during the experiment.

The results of the experiment (shown in Table 1) indicate that the application of chicken manure compost gave as good a grain yield (7.43 mt/ha) as the conventional farming which used only chemical fertilizer. On the other hand, the quality of the brown rice from the intermediate farming and organic farming plots seemed to be better, since it had a significantly higher phosphorus content and a slightly higher potassium content than rice grown by conventional farming (Table 2). The eating quality of organic rice was considered to be better by a panel test, as is indicated by the higher overall value (0.29) (Table 3).

An experiment was conducted by Tsai *et*

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al. (1992) at the Taichung District Agricultural Improvement Station, to see the effect of organic fertilizer on the Vitamin B_2 and Vitamin C content of Chinese cabbage. As shown in Table 4, when the amount of chemical nitrogen fertilizer was doubled or tripled, the vitamin B_2 content fell from 360 ug/g (60 kgN/ha) to only 230 ug/g (120kgN/ha) and 260 ug/g (180 kgN/ha). However, in the plots to which peat and chicken compost had been applied, the vitamin B_2 content reached 390 ug/g and 450 ug/g, respectively. The Vitamin C content also varied greatly according to the type of fertilizer applied.

According to Huang (1993) the eating quality of cabbage and radish produced by intermediate farming (chemical + organic fertilizers) and organic farming systems was better than that of the same vegetables grown by conventional farming (Table 5).

Table 1. Performance of Taichung 189 rice under different cultural systems

Culture system	Plant height (cm)	No. of grains per panicle	% seed set	Grain yield (mt/ha)
Conventional farming	103.4	85.9	83.2	7.43
Intermediate farming	97.2	76.9	82.7	6.22
Organic farming (A)	100.4	76.8	79.3	5.70
Organic farming (B)	109.4	86.3	79.8	7.43

Table 2. Chemical analysis of the brown rice of Taichung 189 under different cultural systems

Cultural system	N	P	K	Ca	Mg	Na	Fe	Mn	Zn	Cu
			(%)					(ppm)		
1. Conventional farming	0.84	0.13^{ba}	0.28	0.025	0.096	0.11	13	26	14	3.8
2. Intermediate farming	0.92	0.23^{a}	0.31	0.022	0.100	0.10	13	26	14	3.8
3. Organic farming (A)	0.85	0.18^{aa}	0.31	0.025	0.099	0.11	12	27	17	3.3
4. Organic farming (B)	0.93	0.21^{a}	0.31	0.023	0.096	0.11	15	28	12	2.9

*: Significantly different at a 5% level by Duncan's multiple range test.

Table 3. Panel test score for eating quality of cooked rice produced under different cultural systems (1st crop 1989: variety Kaoshiung 142)

Cultural system	Grain appearance	Aroma	Flavor	Stickiness	Hardness	Overall
Conventional farming	0.29	0	0	0	0.14	-0.14
Intermediate farming	0.43	0	0	0.14	0.14	0
Organic farming	0.43	0.14	0.43	0.29	0.14	0.29

Table 4. Effects of organic and chemical fertilizers on vitamin B_2 and vitamin C content in the leaves of Chinese cabbage at harvest

	Fertilizer treatment	Vitamin B_2 (μg/g)	Vitamin C (μg/g)
Control (no fertilizer)		60^{d}	14^{e}
Chemical fertilizer	60-50-60 (N-P_2O_5-K_2O)	360^{b}	26^{d}
	120-70-90 (N-P_2O_5-K_2O)	230^{c}	36^{ab}
	180-90-120 (N-P_2O_5-K_2O)	260^{c}	38^{ab}
Organic fertilizer	Bark compost (6mt/ha)	350^{b}	29^{cd}
	Peat (6mt/ha)	390^{b}	20^{a}
	Chicken comp (6mt/ha)	450^{a}	38^{ab}
Organic fertilizer + chemical fertilizer	Bark (3mt/ha) + Chemical fertilizer	320^{b}	33^{bc}
	Peat (3mt/ha) + Chemical fertilizer	370^{b}	19^{a}
	Chicken (3t/ha) + Chemical fertilizer	340^{b}	39^{a}

Table 5. A comparison of the eating quality of cabbage and radish grown by different farming systems

Crop	Farming method	Appearance	Panel test quality			
			Sweetness	Flavor	Texture	Overall
Cabbage	CF	7.67	6.70	7.14	6.55	6.94
	IF	7.40	7.01	7.08	6.72	7.28
	OF	6.92	7.31	7.40	7.18	7.55
Radish	CF	7.74	6.93	6.52	6.64	6.79
	IF	7.18	6.77	6.74	6.53	6.61
	OF	7.08	6.82	7.29	6.83	7.11

1: CF: Conventional Farming; IF: Intermediate Farming; OF: Organic Farming

PEST MANAGEMENT IN SUSTAINABLE AGRICULTURE

Pest control should be based on a thorough understanding of the habitual behavior of the pest, so that the most effective biological, cultural, and chemical controls can be combined into an ecologically and economically sound integrated pest management (IPM) strategy. In other words, the aim of IPM is to maximize natural and cultural controls, and use pesticides only as a last resort.

Crop Rotation and Interplanting

Crop rotation systems offer many advantages in the management of soil structure, fertility and erosion, as well as aiding in the control of various pest species. Although crop rotation may be useless in controlling highly mobile insects, pathogen spores, or airborne weed seeds that move readily from field to field (Francis and Clegg 1990), it is effective in controlling soilborne diseases. For instance, fusarium may be reduced by a proper rotation or intercropping with leek and green onion.

An experiment on intercropping conducted at the Taichung District Improvement Station (Wang *et al.* 1990) indicated that potato plants yielded 5-7% more when they were intercropped with grain legumes (snap bean, green shell bean and green pea) in comparison with the yield of monocropped po-

tato (Table 6). The incidence of pest epidemics was much lower in the intercropped field.

Use of Yellow Sticky Plates to Control Insects

Experiments have been carried out in Taiwan (Liu *et al.* 1993) to explore the possibility of catching and killing insects in the field using colored sticky plates coated with insecticide (Omethoate). The results indicated that yellow plastic plates coated with insecticide gave good control of leaf miners. Since this method does not spray insecticide directly onto crops, environmental pollution can be avoided. Different species of insects may be attracted by different colors, so separate experiments should be conducted for the control of different insects.

The Use of Natural Pesticides in Sustainable Agriculture

As natural pesticides are prepared from natural products, the application of such materials may avoid any unfavorable impact on the environment. They are now used widely in sustainable agriculture for the control of diseases and insects in Japan, the United States, and many other countries. According to our preliminary study, a solution of tobacco leaf extract is effective in controlling aphids, snails, and leaf rollers and some other insects. Extract of hot pepper can be used to control aphids, leaf mites, ants and some virus diseases transmitted by aphids. Garlic oil can be used to control aphids, leaf mites, powdery mildew, rust, and many other insects and diseases etc. Spraying plants with vinegar can control powdery mildew disease while combining vinegar with fermented sugar and effective microorganisms gives more effective control of both insects and diseases.

Integrated Control of the Pear Insect Pest Aphanostigma piri Cholodkousky

Pear phylloxera, *(Aphanostigma piri*) is currently a very troublesome insect pest in Taiwan. Each year it moves from the shoots onto the fruit, causing fruit cracking and rotting. Spraying the trees with insecticides is usually ineffective, because the tiny insect has usually already moved onto the small pear fruits by the time they are bagged*. Our experiments indicated that dipping the scions in 80% Sulfur D.F. at a 200x or 400x dilution for two minutes gives effective control (100%) of this insect before the scion is grafted onto the mother tree. However, the insects move from the shoots of the mother tree onto the fruit at a later stage, and control then becomes very difficult. The possibility of using non-insecticidal materials to interrupt the passage of the insect from the shoot onto the fruits was tested by Liu *et al.* (1993). The results indicated that smearing vaseline around the neck of the fruit-bearing shoots gives complete protection from damage by this insect, while smearing grease gives 90% protection (see Table 7).

Control of Kanzawa Spider Mites by Plant Nutrient Supplements

An experiment was carried out using commercially available nutrient supplements to see whether they had any effect on Kanzawa spider mites, in addition to their nutritional effect. The results indicated that spraying the underside of crop foliage with any of three supplements (Fiji nutrient solution, urea, or milk powder + ethanol) can give 80-96% control of two-spotted spider mites (*Terranychus urticae* Koch) and Kanzawa spider mites (*T. Kanzawa* Kishida). This is comparable with the control effect of a chemical pesticide, 25% Morestan W.P. 500x dilution (Table 8). The possibility of killing other insects by plant nutrient supplements is to be explored further.

Control of Two-spotted Spider Mites by Non-Pesticidal Materials

Ordinary detergents used in the home were tested for their effectiveness in controlling two-spotted spider mites on rose plants. The results indicated that under laboratory conditions, Bailan liquid detergent, Salatt dish washing liquid and ordinary detergent killed 72-78% of the insects. However, the control effect fell to 31-87% under field conditions. The effectiveness of killing two-spotted spider mites by safe non-pesticidal materials is only about one half that of a chemical pesticide (25% Morestan W.P.) (Table 9). Nevertheless, the non-chemical method is safe for human health, so is worth using in crop production.

Extension of Sustainable Agriculture in

* Pears and other high-value fruits are often protected on the tree by wrapping the young fruit in paper bags. Temperate pears are grown in the subtropical lowlands of Taiwan by grafting scions from a temperate environment onto the mother trees every year. Ed.

Table 6. Yield of potato as affected by the intercropping of grain legumes

Cropping system	Yield (mt/ha)	Index
I. Potato monocropping	16.72	100
II. Potato intercropped with		
(1) snap bean	17.55	105
(2) green bean	17.81	107
(3) green pea	17.76	106

Table 7. The use of non-insecticidal materials to control the pear phylloxera, *Aphanostigma piri* Cholodkousky

Treatment	No. of shoots observed	No. of infected shoots	No. of insects	Rate of control (%)
Vaseline	100	0	0	100.0
Grease	100	2	11	90.9
Black PE sheets	100	13	179	40.9
Camphor oil	100	17	247	22.7
Check	100	22	359	0.0

Source: Liu 1993

Table 8. The effect of plant nutrient supplements on Kanzawa spider mites on snap bean

Commercial name of plant nutrient supplement	Dilution	Mortality (%) Days after spraying	
		3	7
Fuji 4551	1000x	76.8	96.2
Fuji 8331	1000x	60.6	94.5
Politer	500x	44.8	8.0
Sea-king Star	1000x	61.8	42.6
Kan-lu essence	1000x	71.4	92.0
Seaweed essence	1000x	81.7	84.4
Fish essence	600x	47.7	0
Carbohydrates (Man-tien-chin)	600x	53.1	92.2
Urea	200x	78.8	96.9
Milk powder (100x) + ethanol (50x)		80.9	88.2
25% Morestan W.P.	500x	83.0	88.2
Control (water)		0	0

Source: Liu 1993

Table 9. Effect of non-pesticidal materials on two-spotted spider mite on rose plants

Treatment	Dilution	Rate of killing (%)	
		In laboratory	In field
1. Bailan liquid detergent	1000x	72.6	45.2
2. Salatt dish Washing liquid	1000x	89.7	31.2
3. Ordinary detergent	1000x	71.9	43.7
4. Spreading agent	1000x	84.7	-
5. Action research	1000x	78.4	87.4
6. 25% Morestan W.P.	500x	90.0	97.3
CK (Water)			

Source: Liu 1993

Taiwan

In 1986, various small model plots for organic farming were set up all over Taiwan to demonstrate the usefulness of organic manure to farmers. At the same time, green manure demonstration plots were also set up in farmers' fields, paid for by government subsidies. As a result of these demonstrations, farmers began to apply more organic manure to their crops, but these were mainly fruit tree crops such as pear and peach. Application of organic manure to upland crops and rice is still rather limited, because these crops give less profit.

In 1989, two integrated demonstration farms growing vegetables by organic methods were set up, each with 11 participating farmers. Their operations were not very successful because of the farmers' lack of experience in natural methods of pest control. A government-sponsored Organic Production and Marketing Team was established in 1990 to produce sponge gourd by organic methods. Green manure crops were grown on two-thirds of the land to increase the nitrogen source. To the remaining land was applied 2 mt/ha of composted cattle manure and soybean meal, plus silica slag as the basic fertilizer. No chemical pesticides were used, only available non-chemical IPM methods. These operations resulted in a 25% increase in the yield of high-quality sponge gourd, so this is considered to be one of Taiwan's first successful organic farms.

In 1990, a ten-hectare organic citrus farm was established, and has also proved very successful.

In 1991, six model farms were set up to demonstrate organic farming techniques for six different kinds of crop: rice, sponge gourd, bitter melon, Liucheng, star fruit, and grape. The farmers are encouraged to use self-made compost as fertilizer, and to control pests by using many different non-chemical methods including fruit bagging, baiting, or spraying with sugar-vinegar-microbic solution, charcoal oil, camphor oil, tobacco or hot pepper extract, and many other natural pesticides. This demonstration has been successful, and it is suggested that the number of organic farms be expanded gradually to maintain a good market demand for the produce.

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