

CURRENT STATUS OF ORGANIC MATERIALS RECYCLING IN SOUTHERN TAIWAN

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ABSTRACT

This Bulletin discusses the use of organic wastes in southern Taiwan for increasing crop production, maintaining soil fertility and reducing production costs. In general, the composting of organic wastes and their application to improve soil fertility are well developed. Since both the nutrient levels and the heavy metal content of most composts are low, the timing and rate of their application are not critical. However, compost with a high nutrient content, and/or a high level of heavy metals, should be used with caution in order to prevent soil pollution.

The application of hog or chicken manure combined with chemical fertilizer improved both the yield and quality of crops. This type of combined chemical/organic application also had fewer adverse effects on arable land. The ratio of nutrients or the rate of their release may not always match the needs of the plant, but the combined use of chemical and organic fertilizers can correct any deficit.

Composted livestock manure can be used to substitute for around 20% of the growing medium in pot culture.

INTRODUCTION

Large quantities of agricultural by-products and animal waste are produced each year in Taiwan. These include about 730 thousand mt of swine manure, 1,860 thousand mt of chicken manure, 300 thousand mt of cattle manure, 310 thousand mt of sugarcane bagasse, 310 thousand mt of straw, 17 thousand mt of rice husk, 50 thousand mt of bark, 70 thousand mt of fruit and vegetable wastes from markets, 50 thousand mt of mushroom wastes and 5 thousand mt of coconut wastes. In order to reduce the pressure on land-fill sites and conserve natural resources, we should compost these organic wastes and recycle them onto arable land. Organic materials contain plant nutrients, and their use will reduce the amount of chemical fertilizer which Taiwan needs to import or manufacture.

The island of Taiwan has a subtropical climate, with relatively high temperatures and humidity all year around. The level of microbial activity in compost is high, and the organic carbon conversion

rate is also high. According to Wang (1989), the organic carbon consumption per hectare is around 20 mt/year. A suitable amount of organic manure is urgently needed to maintain the organic matter content of the soil at an appropriate level. In recent years, the treatment and recycling of organic wastes has become an important topic in Taiwan.

EFFECT OF ANIMAL WASTE COMPOST ON CROP YIELDS AND SOIL QUALITY

Nitrogen value of composted cattle manure

Continuous field trials were carried out over three years (1995 - 1999) in Lu-Chiao, Central Taiwan, to check the nitrogen fertilizer value of composted cattle manure. The soil where the trials were carried out was a silt loam with a pH of 7.4 and an organic matter content of 28 g/kg. Three crops were grown each year in rotation: cabbage, and spring and summer crops of rice.

Keywords: chemical fertilizer, combination, compost, organic farming, soil fertility, Taiwan

Each crop received treatments either of NPK, or of composted cattle manure at various rates (see Table 1). The nitrogen content of the composted cattle was equivalent to 1.0, 2.0 and 3.0 times the nitrogen in the applied chemical fertilizer. The yield response of the three crops to the various treatments is shown in Table 2.

It can be seen that the yield response of crops to nitrogen in compost was lower than the response to chemical fertilizer. The relative nitrogen efficiency of compost for cabbage was 0.276, while that for rice was 0.232 - 0.297 (Table 3). The data indicate that the value of nitrogen in composted cattle manure was only about 25% that of chemical fertilizer. However, after repeated applications, the N-value of compost increased gradually year by year.

N-fertilizer value of compost made from various kinds of livestock manure (cattle, hog and chicken) was further tested in two soil series, using rice, cabbage and peanut as indicator crops. The properties of the compost are shown in Table 4. Of the soil series tested, both were recent alluvial soils, one with a pH of 5.1 (Tou-Nan), and one a calcareous soil with a pH of 7.9 (Yi-Chu).

The effect of compost on the yields and yield index of rice, cabbage and peanut are shown in Table 5. It is clear that the effect of the compost varied, according to the kind of soil and crop (Table

6). For rice yields, the relative N-value of chicken manure was the highest, but was only 37% of the N-value of chemical fertilizer. Cattle manure was the second, (34%) and hog manure lowest (32%). For cabbage, the hog manure was the highest (37%) followed by chicken manure (29%) and cattle manure (25%). For peanut, cattle manure was the highest (21%), followed by hog manure (19%), and chicken manure (11%).

Sorenson and Jensen (1995) have indicated that the mineralization rate and the amount of nitrogen released from compost varies according to the soil texture. Our experiments gave the same results. In the short term, it seems that the nitrogen present in compost is less efficient than the nitrogen in N fertilizer. However, in the long term, at the end of two years of tests, the soil zinc content in all plots with applied compost was higher than the plot given chemical fertilizer. The plot treated with composted hog manure had a higher accumulation of copper, from the copper sulfate often included in the diet of pigs for growth promotion. The levels of phosphorus and potassium were also high, especially in plots treated with hog and chicken compost.

Long-term effects of composted animal wastes on soil fertility and crop yield

Experiments were carried out in order to

Table 1. Crops and compost used in the field experiment

Treatment	Cattle manure			Chemical fert. N-P ₂ O ₅ -K ₂ O kg/ha
	Autumn cabbage	Spring rice mt/ha	Summer rice	
1. Cattle manure (1.0 N)	15	10	10	0
2. Cattle manure (2.0 N)	30	20	20	0
3. Cattle manure (3.0 N)	45	30	30	0
4. Control 0N	0	0	0	0
5. Chemical (1.0 N)				
Autumn cabbage	0	-	-	240-80-120
Spring paddy rice	-	0	-	160-90-60
Summer paddy rice	-	-	0	160-90-60
6. Intermediate (cattle manure 0.5 N, chemical 0.5 N)				
Autumn cabbage	7.5	-	-	120-40-60
Spring paddy rice	-	5	-	80-45-30
Summer paddy rice	-	-	5	80-45-30

Table 2. Yield of three crops given chemical fertilizer and compost treatments, 1995-99. Figures in parentheses are the yield index (%).

	mt/ha			
	1.0 N compost	2.0 N compost	3.0 N compost	1.0 N chem. fert.
Cabbage	47-53 (55-61)	65-72 (75-82)	72-81 (84-91)	82-89 (100)
Spring rice crop	4.7-5.2 (72-74)	5.2-6.1 (80-83)	5.7-6.5 (88-91)	6.4-7.2 (100)
Summer rice crop	4.3 (77-79)	48-5.1 (89-91)	5.1-5.5 (92-97)	5.5-6.6 (100)

Table 3. Relative nitrogen efficiency of cattle manure for various crops

	Relative N-value (kg N/ha)				Regression equation
	0 N (Control)	1 N	2 N	3 N	
Cabbage	0	70-87	145-165	178-205	$Y=8.62 + 0.276 X$ ($R^2=0.97$)
Spring rice crop	0	39-54	63-89	94-124	$Y=3.53 + 0.232 X$ ($R^2=0.95$)
Summer rice crop	0	49-61	101-121	124-153	$Y=5.36 + 0.297 X$ ($R^2=0.96$)

evaluate the feasibility of organic farming in Southern Taiwan. Three farming methods and two cropping systems were tested, at a site with sandstone and slate mixed alluvial soils. The three farming methods were:

- Conventional with recommended chemical fertilizer and pesticides;
- Intermediate (half chemical fertilizers were used, and half organic);
- Organic (no chemical pesticides and only organic fertilizers were used).

The rate of chemical fertilizer applied to each crop is listed in Table 7. The results showed that the soil pH, the level of phosphorus in the soil, and the soil organic matter content all increased over time in the organic plot (Fig. 1, Fig. 2, Fig. 3). In the chemical plot, they all decreased. The level of soil exchangeable potassium also rose slightly in both the organic and mixed plots and fell in the chemical plot (Fig. 4). The plot which combined chemicals and organic inputs had the best ability to build up soil nitrogen, and produced the highest crop yield. However, the nitrate content of the harvested crop was also high.

For cabbage, conventional farming methods gave the highest yields, probably because of crop losses from pests in the organic plots. The same was true of lettuce. Corn yields were generally higher in

the organic and mixed plots than in the conventionally farmed plot. Yields in all plots were relatively high, showing that suitable crops or varieties, grown using modern cultivation techniques by experienced growers, gave a good harvest (Fig. 5).

Thus, it seems that organic farming can be practiced successfully in southern Taiwan. Soil fertility will improve if organic methods are used. However, Chao studied the soil from the organic farming plot, and found that the levels of 0.1 extractable zinc increased from 11.5 mg/kg at the beginning of the treatment to 27.8 mg/kg at the end. Similarly, copper increased from 10.0 to 29.1 mg/kg. With long-term compost applications, it is necessary to monitor the accumulation of toxic substances such as heavy metals.

EFFECTS OF COMPOSTED LIVESTOCK MANURE ON WAX-APPLE

Studies were made of the effect of composted animal waste on the yield and quality of wax apple (*Syzygium samarangense* Merr. Perry). Experiments over four years showed that the compost plot had a higher soil pH and a higher content of calcium and magnesium than the chemical plot. However, plant biomass, fruit yield, and the sweetness and size of

Table 4. Properties of animal waste compost used

	pH	Moisture	N	P g/kg	K	Ca	Mg	Cu mg/kg	Zn
Cattle manure	7.5	350	18.1	10.3	34.4	4.6	12.5	96	278
Chicken manure	7.8	160	24.6	26.2	35.4	48.3	10.9	78	410
Hog manure	7.2	310	28.2	32.9	28.9	16.4	22.0	561	444

Table 5. Yield and yield index of rice, cabbage and peanut

Treatments	Rice (Yi-chu)		Rice (Tou-nan)		Cabbage		Peanut	
	Yield kg/ha	Index %	Yield kg/ha	Index %	Yield ton/ha	Index %	Yield kg/ha	Index %
Cattle manure 1.5 N	5948	84	5697	79	62.0	65	2005	91
Cattle manure 3.0 N	7218	101	6975	97	79.1	83	1909	86
Chicken manure 1.5 N	7139	100	6614	92	77.8	81	1894	86
Chicken manure 3.0 N	7458	105	6572	91	86.5	90	1665	75
Hog manure 1.5 N	7472	105	6952	96	98.1	102	1702	77
Hog manure 3.0 N	7030	99	6230	86	104.6	109	1880	85
Control 0 N	4315	61	4013	56	20.4	21	1413	64
Chemical 0.5 N	6199	87	6222	86	76.8	80	1865	84
Chemical 1.0 N	7115	100	7208	100	95.8	100	2213	100

Table 6. Relative nitrogen efficiencies of animal waste compost for various crops

	Relative N- value (kg N/ha)			Regression equation	
	0 N (Control)	1.5 N	3.0 N		
Spring paddy rice					
Cattle	0	93	166	$Y = 3.46 + 0.345 X$	$(R^2 = 0.98)$
Chicken	0	161	180	$Y = 23.8 + 0.374 X$	$(R^2 = 0.72)$
Hog	0	180	155	$Y = 34.3 + 0.323 X$	$(R^2 = 0.59)$
Summer paddy rice					
Cattle	0	85	149	$Y = 3.44 + 0.309 X$	$(R^2 = 0.94)$
Chicken	0	130	128	$Y = 22.0 + 0.268 X$	$(R^2 = 0.66)$
Hog	0	148	111	$Y = 30.7 + 0.231 X$	$(R^2 = 0.47)$
Cabbage					
Cattle	0	132	187	$Y = 13.0 + 0.259 X$	$(R^2 = 0.94)$
Chicken	0	183	211	$Y = 25.8 + 0.292 X$	$(R^2 = 0.85)$
Hog	0	247	268	$Y = 37.8 + 0.372 X$	$(R^2 = 0.81)$
Peanut					
Cattle	0	30	25	$Y = 5.74 + 0.207 X$	$(R^2 = 0.55)$
Chicken	0	24	13	$Y = 5.85 + 0.108 X$	$(R^2 = 0.25)$
Hog	0	14	23	$Y = 0.92 + 0.194 X$	$(R^2 = 0.73)$

fruit, were the same in organic and chemical treatments (Table 8).

Half organic plus half chemical fertilization gave a better average weight per single fruit. However, the cost of organic fertilizer was 20 times higher than that of chemical fertilizer. While very light applications of compost lowered fruit yield, large ones tended to accumulate excess nutrients in the soil. Chen *et al.* (2001) suggested that half organic and half chemical fertilizer is best for wax apple orchards.

USE OF ORGANIC WASTES AS SUBSTITUTES FOR GROWING MEDIA

Taiwan imports a large quantity of growing media each year for the cultivation of pot plants. The most common imported media are peat moss, perlite, vermiculite and tree-fern. Recently, EC countries have begun to prohibit the mining and selling of peat moss and similar materials. Now that the supply is limited, we need to find local substitutes. Ideal growing media should have good physical, chemical and biological properties which produce healthy plants.

Pot culture media for cucumber seedling

Organic wastes from agriculture and aquaculture production were composted and used as a substitute growing medium for cucumber seedlings. The chemical properties and nutrient content of the compost and media were analyzed, as shown in Table 9. Composts based on various raw materials were evaluated, according to the growth of the seedlings. All the composts could supply the nutrients needed by the seedlings without any additional chemical fertilizer.

Compost for sale in Taiwan contains a high level of soluble salts (EC), which makes them less suitable as growing media for pot plants. Tsai (2001) selected 20 brands of commercial compost, and mixed them with peat moss at a ratio of 1:1 as media for cucumber seedlings grown in pots. He found that only three brands of compost were suitable for this purpose. All three had a particle size of 0.6 - 2.0 mm diameter, a pH of 6.35 - 8.87, an EC of 1.69 - 2.31 dS/m, an organic matter content of 620 - 870 mg/kg, and a total nitrogen content of 13.0 - 19.3 g/kg, with 4.7 - 12.3 g/kg phosphorus, 7.5 - 12.5 g/kg potassium, 12.4 - 17.2 mg/kg calcium, and 2.8 - 7.3 mg/kg manganese. Tsai (*ibid*) also found that several commercial compost products were good

for the growth of cucumber seedlings when mixed with peat moss, coconut fiber, vermiculite or wood chips at a ratio of 1:1 (Table 10). However, rice hull and bagasse were not suitable. From the point of view of production costs, wood chips and coconut fiber were promising substitutes for growing media.

GROWING MEDIA FOR ARUM LILIES

Various species of arum lilies (Araceae) are common pot plants in Taiwan. Over a million of them are sold in the market each year. Arum lilies are grown in media which have a neutral reaction and a water-holding capacity of 30 - 60%.

Bark compost, bagasse, coconut fiber and carbonized rice hull were tested, mixed with each other or with peat moss. The tested plants grew normally in all mixed media and were comparable to those grown in peat moss only. Some species grew better in coconut fiber mixed with peat moss, others preferred media mixed with bark compost. A similar treatment used to test *Spathiphyllum* Petite, a vegetatively propagated pot plant, showed that media mixed with carbonized rice hull produced plants with more tillers.

Compost from animal manure as a substitute for growing media for pot plants

Sludge sediments from livestock manure were composted and used as a substitute for pot plant growing media. About 10% to 20% was used (by volume). Several species of ornamental plant, including Philodendron and *Spathiphyllum*, were tested. Results showed that media containing 20% composted sludge had the same results as pure media, or even better. The same was seen when 20% composted chicken manure was substituted for growing media.

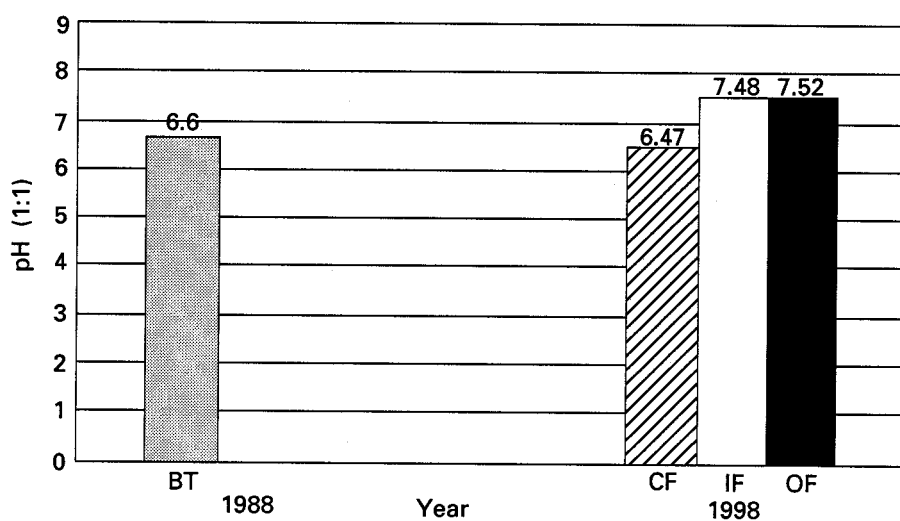
In general, there was no effect on the length and width of leaves, if composted chicken manure was added. However, plants growing in media with a high percentage of coconut fiber had more leaves. Chicken manure compost has a high pH, and adding it to growing media raised the pH. This change in pH does not always benefit in correcting the acidity of the media.

The high EC of chicken manure compost may be another limitation to its usage. Our experimental results showed no harmful effect from substitution, even when the coconut fiber had a high EC. It seems that the addition of up to 20% composted livestock

Table 7. Rate of chemical fertilizer applied to crops

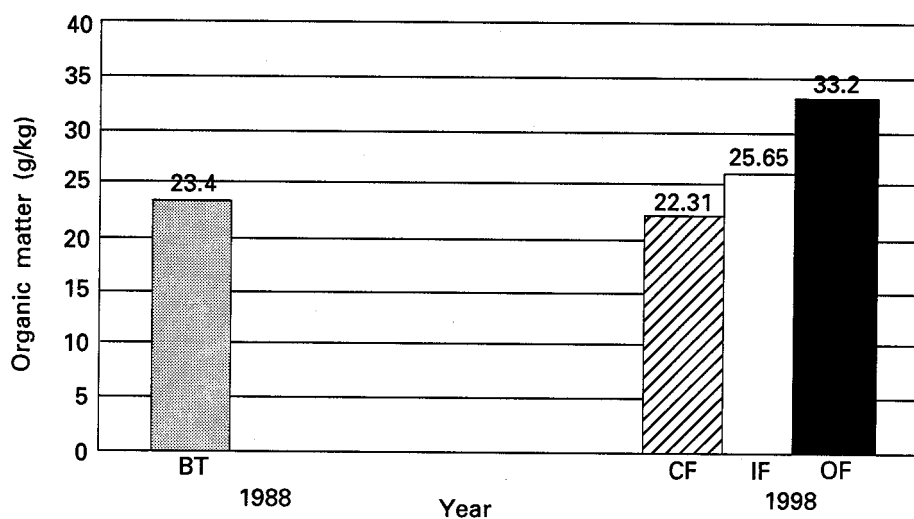
Crops	N	P ₂ O ₅ kg/ha	K ₂ O
Sweet corn	178	56	60
Vegetable soybean	60	72	60
Cabbage	200	32	70
Radish	150	100	108
Lettuce	255	218	182
Paddy rice	120	40	60

Source: Shyu and Tsai (1999)



BT: Value before test; CF: Conventional farming; IF: Intermediate farming (mixed organic/conventional); OF: Organic farming

Fig. 1. Effects of different types of farming on pH of soil



BT: Value before test; CF: Conventional farming; IF: Intermediate farming (mixed organic/conventional); OF: Organic farming

Fig. 2. Effects of different types of farming on organic matter content of soil

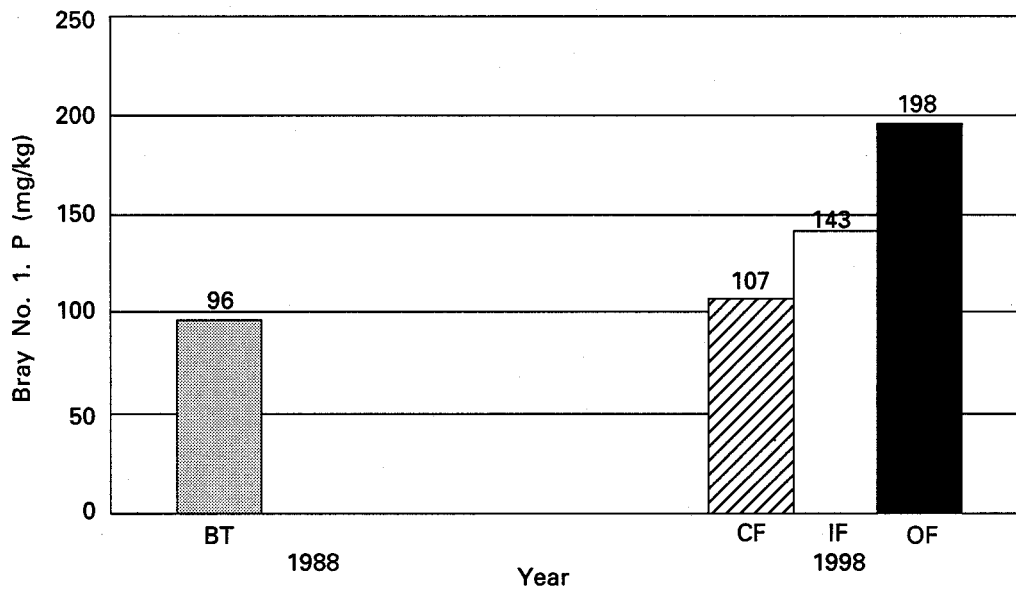
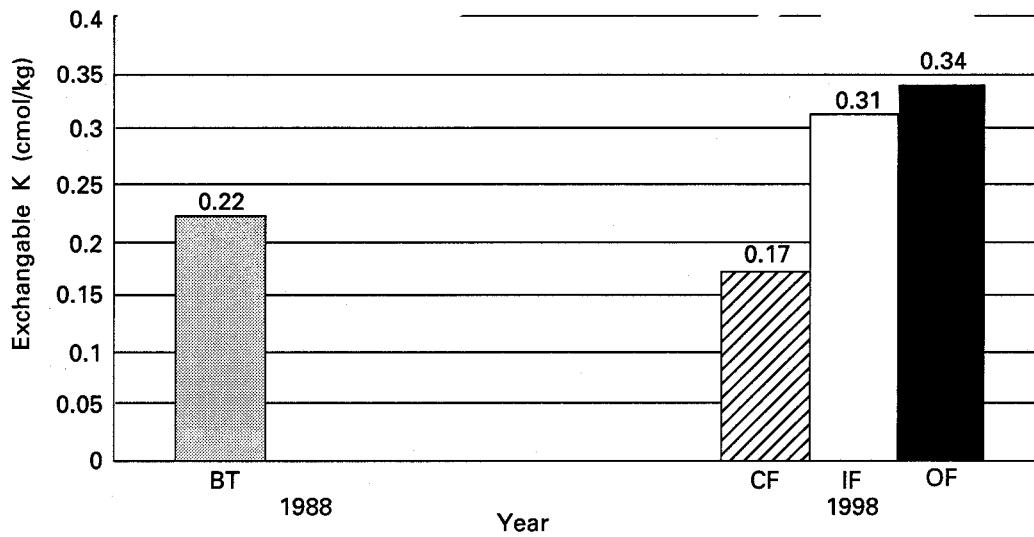
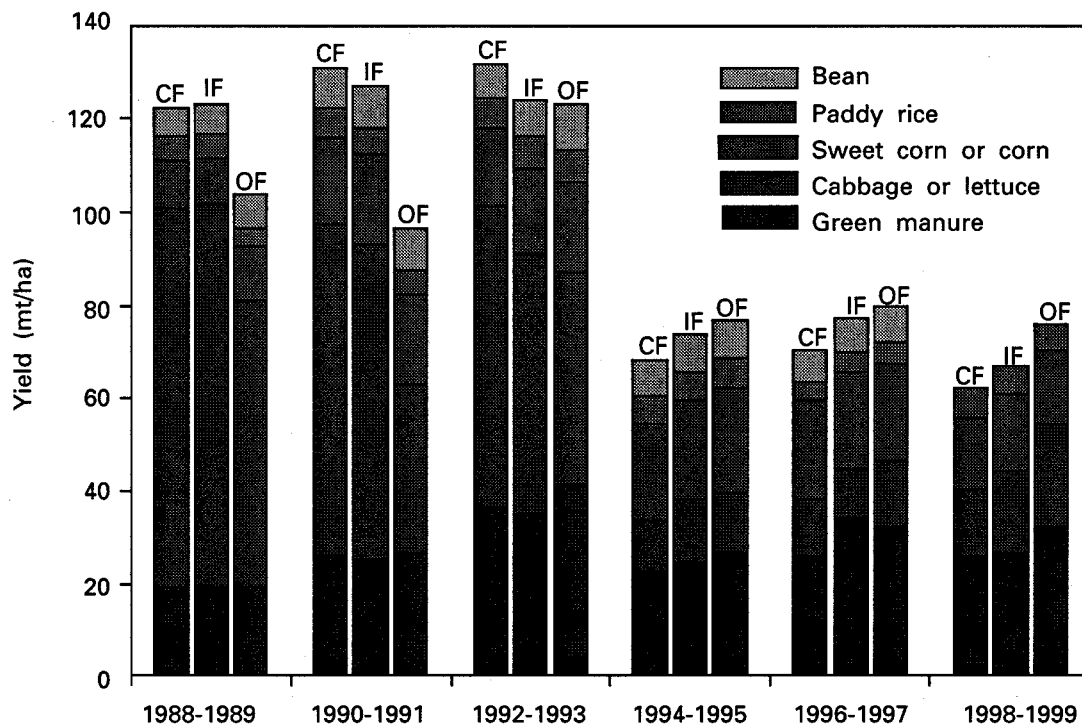


Fig. 3. Effects of different types of farming on available P in soil
 BT: Value before test; CF: Conventional farming; IF: Intermediate farming (mixed organic/conventional);
 OF: Organic farming



BT: Value before test; CF: Conventional farming; IF: Intermediate farming (mixed organic/conventional);
 OF: Organic farming

Fig. 4. Effects of different types of farming on exchangeable K in soil



CF: Conventional farming; IF: Intermediate farming (mixed organic/conventional); OF: Organic farming

Fig. 5. Comparison of crop yield under different types of farming and cropping systems

Source: Tsai 2001

Table 8. Effect of fertilization on soil properties of wax apple orchard at 1st and 5th year^{a)}

Treatment	pH	OM %	P	K	Ca mg/kg	Mg	Mn	Na	B.D. ^{b)} g/ml
A ^{c)}	5.9 ^{d)}	2.77	254	200	2159	107	42	88	1.37
	5.7 ^{e)}	2.45	205	162	5061	232	25	240	1.38
B	6.7	2.88	237	152	5513	263	58	121	1.41
	7.0	3.12	221	164	3167	459	50	94	1.38
C	6.9	3.19	227	165	6456	296	56	146	1.36
	7.2	3.15	293	189	6200	545	58	100	1.32
D	6.8	2.93	248	172	4016	205	48	130	1.38
	6.9	2.99	234	156	4720	322	39	63	1.38
E	6.7	2.94	231	210	4474	335	65	95	1.42
	6.7	3.08	233	184	4542	348	42	204	1.38

Note: a) Source from Chen *et al.* (1999)

b) B.D. = bulk density.

c) A: Chemical fertilizer application: N-P₂O₅-K₂O = 1.6-1.8-1.8 kg/plant.

B: Organic fertilizer application: N-P₂O₅-K₂O = 1.6-1.8-1.8 (1.63-1.81-1.52) kg/plant, about 20 mt/ha.

C: Organic fertilizer application: N-P₂O₅-K₂O = 2.4-2.7-2.7 (2.38-2.56-2.25) kg/plant, about 30 mt/ha.

D: Organic fertilizer application: N-P₂O₅-K₂O = 0.8-0.9-0.9 (0.81-0.96-0.78) kg/plant, about 10 mt/ha.

E: Half chemical and half organic fertilizer: N-P₂O₅-K₂O = 1.6-1.8-1.8 (1.63-1.85-1.68) kg/plant.

() indicated the 4-year average nutrients used.

d) Row indicates 1st year soil data.

e) Row indicates 5th year soil data.

Table 9. Chemical properties of compost media^{a)}

Compost media	pH (1:5)	EC (1:5) dS/m	NH ⁴⁺ -N mg/kg	NO ³⁻ -N mg/kg	TN g/kg	TP g/kg	TK
M1 ^{b)}	7.77	4.54	25.7	584	11.2	5.0	3.3
M2	7.87	4.91	50.0	534	13.3	5.7	4.9
M3	7.93	5.22	36.0	329	15.4	10.2	5.7
M4	7.73	10.88	69.3	219	14.7	6.8	8.8
P	6.99	0.29	NS	NS	4.0	0.9	1.5
M1:P = 1:3	7.20	1.35	6.4	146	5.8	1.9	2.0
M1:P = 1:5	7.12	1.00	4.3	97	5.2	1.6	1.8

Note: a) From Tsai (1997).

b) M1: Compost is made of peanut hulls and shrimp shells at a ratio of 100:140.

M2: Compost made of peanut hulls, shrimp shells and rice bran at a ratio of 100:120:35.

M3: Compost made of peanut hulls, shrimp shells, rice bran and slaked lime at a ratio of 100:120:35:2.

M4: Compost made of peanut hulls, shrimp shells, rice bran and seaweed at a ratio of 100:120:35:16.

P: peat moss.

Table 10. Growth response of cucumber seedlings on composted media mixed with various components (50:50), (28 days after sowing)

	Plant height (cm)	Leaf length (cm)	No. of leaves	Fresh weight g/plant	Twisted roots (%)	Seedlings (%)
Peat moss	15.97	6.86	2.03	4.47	100	100
Coconut fiber	16.38	7.48	2.07	4.64	98	100
Vermiculite	15.17	6.33	2.01	4.30	100	100
Wood chips	13.01	5.61	1.87	3.88	100	100
Rice bran	14.29	6.82	2.32	3.87	85	94
Bagasse	5.69	4.51	1.41	1.77	95	96
LSD (5%)	3.79	1.66	0.38	1.12	7	7

Source: Tsai (1999)

Table 11. Cost estimation of media components

Component	Bulk density g/ml	Moisture %	Cost US\$	US\$/L
Peat moss ^{a)}	0.10 ^{b)}	45	16/250L/bundle	0.06
Bagasse compost ^{c)}	0.087	25	3.3/8kg/bundle	0.05
Coconut fiber (coarse)	0.707	10	8.3/20kg/bundle	0.03
Coconut fiber (fine)	0.092	15	5/80L/bundle	0.06
Bark compost	0.54	49	4.5/20kg	0.24
Carbonized rice husk	0.088	6	0.3/kg	0.03

Note: a) Imported from Southeast Asia

b) Average cost

c) Piled up outdoors for one year.

1US\$ = 30NT\$

manure is safe for pot culture.

Table 10 shows the price of organic materials for sale in Taiwan. Rice hull and bagasse compost are relatively cheap. However, before growers decide to use them as media substitutes, they should consider the growth and quality of pot plants, and their sale price, as well as the production cost.

CONCLUSION

Organic wastes from agricultural production are an important resource for farms in Taiwan. Recycling organic wastes onto arable land can provide some of the plant nutrients needed by crops, and maintain soil fertility. However, most organic wastes have a low plant nutrient content, and their rates of nutrient release are also low. It is important to compost organic wastes before they are applied to crops.

The relative nitrogen efficiency of compost made from animal wastes was low in comparison to chemical fertilizer. The N-efficiency of composted cattle manure and chicken manure was 0.345 and 0.374, respectively, in paddy rice. It was only 0.207 and 0.108 in peanut fields.

Some organic wastes were found to contain a high level of heavy metals, which limited their use. If compost is applied regularly, the nutrient levels of soils and plants, and their heavy metal content, must be checked periodically to prevent nutrient imbalances and soil pollution.

The rational application of compost can increase crop production and product quality. A combination of organic and chemical fertilizer gave better results than either type of fertilizer used alone. Coconut fiber and bark compost can be used as growing media for pot plants and seedlings. Composted animal wastes can be used to substitute for growing media for pot plants. However, their proportion (in volume) to peat moss should not be more than 20 - 25%.

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