PN-ABH-900

TOPIC CODE EB A,C,E,F

REF: FFTC EB 315
ISSN 0379-7597

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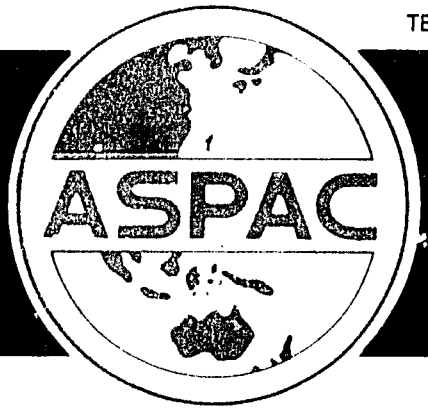

FOOD & FERTILIZER TECHNOLOGY CENTER

THE USE OF ORGANIC MATTER IN CROP PRODUCTION

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Taichung, R.O.C. on Taiwan

EXTENSION BULLETIN NO. 315

November 1990

FOREWORD

Chinese farmers have traditionally shown great skill in the use of organic fertilizers in crop production. However, the use of organic fertilizers has been declining in ROC on Taiwan as farmers have replaced them with the more compact and convenient chemical fertilizers. In recent years, both farmers and agronomists have become aware that repeated heavy applications of chemical fertilizer can harm the soil and reduce productivity. There is now a new interest in using organic fertilizers, often in combination with chemical ones.

This important Bulletin reviews the use of organic matter in modern farming, and discusses its effect on the crops and soil. The various kinds of organic materials used as fertilizer in Taiwan are reviewed, in terms of their nutrient content and other characteristics. Simple and practical techniques of composting are described, together with a brief outline of the various processes involved during composting, and ways of judging compost maturity. Finally, the author outlines methods and timing of compost application.

The paper on which this Bulletin is based was first presented by its author at an international seminar on *"The Use of Organic Fertilizer in Crop Production"*, held in Suweon, Korea (June 1990) with the co-sponsorship of the Rural Development Agency of Korea. It is one of a series of five Extension Bulletins (EB 311-315) being published by the Center this year on the use of organic materials as fertilizers for crop production.

THE USE OF ORGANIC MATTER IN CROP PRODUCTION

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(Chinese Abstract) 摘　　要

本篇報告主要介紹台灣常用的一些有機肥料，並討論它們的化學成分和製造使用方法。作者按照其來源的不同，將台灣常用的有機肥料分成10大類如下：1.作物殘株、2.綠肥作物：3.一般堆肥、4.菇類堆肥、5.牛糞堆肥、6.豬糞堆肥、7.禽糞堆肥、8.垃圾堆肥、9.油粕類、10.動物性廢棄物。這些材料做爲堆肥使用都有其優點和缺點，作者都分別描述其適當的處理改進和利用方法。另外對各種有機肥料的施用方法、使用量和使用效果都有重點式的介紹以供各界的參考。

(Japanese Abstract) 摘　　要

台湾で利用されている有機肥料とその化学組成とコンポストの方法を紹介する。有機肥料はその原料によって次の１０種に分類される。作物残渣、緑肥、一般堆肥、マシュルームコンポスト、牛肥、豚肥、家畜肥、都市廃物、油粕、動物性残渣である。それぞれ一長一短であり、これを踏まえた改良施用法を提案した。さらに施用法、使用量、効果について種類別に解説した。

(Korean Abstract) 초　　록

이 논문은 대만에서 일반적으로 사용되고 있는 유기물질을 기술하고 그들의 화학적 조성과 퇴비조제 및 사용방법에 대해서 논의하였다. 그들은 여러가지 재료에 따라 다음과 같이 10가지로 분류하였다. 1. 농업부산물, 2. 녹비, 3. 일반퇴비, 4. 버섯폐상퇴비, 5. 외양간두엄, 6. 돈사두엄, 7. 계분, 8. 도시폐기물, 9. 깻묵, 10. 축산가공 잔유물. 이들 물질은 각각의 이점과 단점들이 있으며 일부에서는 이들 물질에 대한 보다 개량된 사용방법을 추천 제시하고 있다. 이러한 여러가지 종류의 유기물질 시용방법이나 시용량과 작물에 대한 그들의 효과에 대해서 논의하였다.

THE USE OF ORGANIC MATTER IN CROP PRODUCTION

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ABSTRACT

This paper describes the organic manures commonly used in Taiwan, and discusses their chemical components, and the ways in which they are composted and used. They are classified into ten categories, based on their various sources, as follows: 1. Crop residues, 2. Green manure, 3. Common compost, 4. Mushroom compost, 5. Cattle manure, 6. Swine manure, 7. Poultry manure, 8. Municipal refuse, 9. Residues after the extraction of edible oil, 10. Residues from processing animal products. All these materials have their advantages and disadvantages, and the authors suggest some recommendations for their improved utilization. The application methods and rates of these various kinds of organic manure, and their effect on crops, are discussed.

INTRODUCTION

Long before the introduction of chemical fertilizers, our ancestors had already learned to make use of organic material for improving the growth of their crops. It is said that soldiers in the Roman Army discovered that wheat in abandoned stable yards grew much better than wheat in adjacent parts of the farm, indicating the usefulness of horse manure for the production of crops. American Indians used to bury spoiled fish beneath their corn plants, to get better yields. It is still common for aboriginal people to burn bushes and grasses, and then sow their crops beneath the ashes to get better harvests.

It was a common practice on farms in many Asian countries about 30-40 years ago to use rice straw combined with livestock manure for making compost to fertilize crops. Although the use of this somewhat laborious practice of compost making has gradually decreased, due to the increased supply of chemical fertilizers, even nowadays there are some farmers still making compost every year to apply to their soil, because they have learned from experience that compost is the best material for maintaining soil fertility and achieving a higher grade of farm produce.

The importance of organic matter in crop production has been emphasized in recent years, due to the growing interest in organic farming in many countries. As there are many kinds of organic matter and the properties of these vary greatly, it is interesting to make a systematic description of the uses of these materials for crop production. This paper describes the general aspects of organic materials used as fertilizer, with special reference to their inorganic nutrient content, their effect on the physico chemical and biological properties of the soil, and efficient methods of composting and applying these organic materials.

FUNCTIONS OF ORGANIC MATTER IN SOIL

Organic matter is often used as an index of soil fertility. A high level of organic matter in the soil suggests that the soil is relatively fertile, while a low level of organic matter in the soil usually means that the soil is lower in fertility. Generally, organic matter influences soils in three ways: the physical, chemical, and biological properties of the soil. This influence far outweighs the relatively small proportion of organic matter present in the soil. At least 50% or more of the cation exchange capacity (CEC) of the soil is performed by soil organic matter. About 92-94% of soil nitrogen and 15-18% of total phosphorus are released from organic matter.

The term "soil organic matter" covers all kinds of plant tissues and animal residues in the soil. This soil organic matter may turn into humus after decomposition and become an active component of the soil. In general,

humus has a relative weight of 0.3-0.5 with 60-80% porosity. Humus itself is colorless, but it may turn black in color after chemical changes or infection by soil microorganisms.

Physical Functions

The fibrous portion of organic matter plays an important role in the improvement of soil physical properties. Its loose constituency, and high carbon content which promotes the growth of mycelia, promote soil aggregation and improve the permeability and aeration of clayey soils. Its high moisture absorbing power and high carbon content for the growth of mycelia also help the granulation of sandy soils, and improve their nutrient and water holding capacity.

In the cold season, soil organic matter may absorb heat and maintain the soil temperature at a higher level which is more favorable for the growth of plant roots.

Chemical Functions

Organic matter accounts for at least half the cation-exchange capacity of the soil. A high CEC is not only important in retaining applied fertilizers, but is also helpful in increasing the buffering capacity of the soil, so that crops can better cope with various stresses such as soil acidity, nutrient excess, and other unfavorable soil conditions. A high CEC may also help increase the availability of many nutrient elements. According to Wei (1964), the application of compost to sugarcane fields helped increase the efficiency of phosphorus absorption and enlarged the root system of the sugarcane.

Another important chemical function of organic matter is its release of nutrient elements to the crop. The decomposition of organic matter, or the mineralization of the nutrient elements in the organic matter, may release different kinds of nutrients such as nitrogen, phosphorus, potassium, sulphur, and other major and secondary nutrient elements at different rates. A proper combination and utilization of the different organic materials may partly or completely substitute for chemical fertilizers.

Biological Functions

Carbon in organic matter is the main source of energy for the activities of soil microorganisms. Adding organic matter with a high C/N ratio to the soil may stimulate the propagation of soil microorganisms. These are likely to fix soil nutrients in their bodies, causing a temporary shortage of nitrogen in the soil. As the C/N ratio of the organic matter decreases, some of the soil microorganisms may die and decompose, returning their nutrients to the soil.

Applying organic matter to the soil may be either beneficial or injurious to the crop, depending on the type of crop and the type of organic matter. Soil treatment with sawdust, tree leaves, green manure, oil cake, rice bran etc. may promote the multiplication of earthworms, and inhibit nematode populations in the soil. Soil treatment with the straw of Gramineae such as rice may reduce the incidence of wilt and blackleg in potato, and root rot in common bean, pea, and cotton. The application of sugarcane leaves may prevent yellows in banana. However, the application of compost to sorghum usually intensifies the severity of downy mildew, while treating the soil of wheat fields with wheat straw usually increases the severity of root rot disease.

Soil treatment with organic matter may increase the populations of some beneficial soil microorganisms, such as rhizobia for nitrogen fixation, and mycorrhizae for increasing the availability of soil phosphorus.

KINDS AND SOURCES OF THE MAIN ORGANIC MATERIALS

Organic materials in Taiwan may be classified into ten categories on the basis of their origin as follows: crop residues, green manure, common compost, mushroom compost, cattle manure, swine manure, poultry manure, municipal refuse, residues after oil extraction, and residues from processing animal products. The nutrient content of these materials differs greatly. The quantity of each category of organic matter produced in Taiwan is shown in Table 1.

The total amount of organic wastes from major sources produced in Taiwan is estimated to be 18.78 million mt per year (Table 1). Swine manure is the most abundant, with 6 million mt per year. Municipal refuse comes next, with 4 million mt/year. Some of these wastes such as rice straw, with a high C/N

Table 1. Estimated quantity of main organic wastes produced in Taiwan

Type of organic waste	Production (1,000 mt/year)	Properties during fermentation: Water holding capacity	Decompo-sibility	Bulk density	C/N ratio
Rice straw	2,600	Medium	Easy	Low	Large (>20)
Rice hull	600	Low	Difficult	Very low	Large (>20)
Sugarcane leaves	2,100	Medium	Difficult	Low	Large (>20)
Wastes from food factories	600	–	Easy	–	–
Swine manure	6,000	Medium	Easy	Medium	Small (<15)
Manure from other animals	2,500	Medium	Easy	Low	Small
Corn cobs	200	Medium	Difficult	Low	Large (>20)
Municipal refuse	4,040	Medium	Easy	Low	Large (>20)
Wastes from fruit/vegetable markets	90	–	Easy	–	Large (>20)
Bark waste	50	Medium	Difficult	Low	Large (>20)
Total	18,780				

Source: Wang 1989

ratio of more than 40, can be considered primarily as a source of C, while others with a low C/N ratio of less than 15, such as animal manure, can be considered primarily as a source of N.

According to Yen (1989), the nutrient content of poultry manure is much higher than the manure of swine or cattle (Table 3). The daily average excretion of cattle (27.5 kg/head) is the highest, followed by swine (0.85 kg/head) and then poultry with 0.12 kg/head (Table 2). Assuming the N, P_2O_5, and K_2O content shown in Table 4, the total amounts of nutrients in the manure produced by swine, cattle and poultry in Taiwan were estimated to be 108,555 mt of N, 121,113 mt of P_2O_5, and 87,711 mt of K_2O. These quantities are equivalent to 45.5%, 173.7% and 90.1%, respectively, of the chemical fertilizers used annually in Taiwan in 1987 (Table 5).

CHEMICAL COMPONENTS OF ORGANIC WASTES

A chemical analysis of both the nutrient content and hazardous elements in the main catagories of agricultural wastes in Taiwan was carried out. These involved samples of crop residues; compost abandoned after mush-

Table 2. The daily average excretion of swine, poultry and cattle

	Swine	Chicken	Cattle
Feces (kg/head/day)	0.85	0.12	27.5
Urine (l/head/day)	2.70		13.5

Note: Swine: 50 kg body weight
Poultry: Adult chickens
Cattle: 500 kg body weight
Source: Yen 1989

Table 3. Average content of N, P_2O_5 and K_2O in fresh manure of swine, poultry and cattle

Unit: %

	Moisture	N	P_2O_5	K_2O
Swine feces	76.6	0.63	0.92	0.28
Urine	98.0	0.48	0.07	0.16
Chicken feces	65.4	1.66	2.92	1.79
Cattle feces	81.9	0.43	0.38	0.29
Cattle urine	99.3	0.47	0.14	1.32

Source: Yen 1981

Table 4. Daily excretion of N, P_2O_5 and K_2O by swine, poultry and cattle

Unit: g/head/day

	N	P_2O_5	K_2O
Swine	18	9.7	6.7
(ratio)	(1)	(0.54)	(0.37)
Poultry	2	3.5	2.1
(ratio)	(1)	(1.75)	(1.05)
Cattle	182	123.0	258.0
(ratio)	(1)	(0.68)	(1.42)

Note: Swine: 50 kg body weight
Chickens: Adult chickens
Cattle: 500 kg body weight
Source: Yen 1989

room culture; common compost; green manure; municipal wastes; swine, cattle and poultry manure; residues after oil extraction; and animal by-products. The results of these analyses are shown in Tables 6-13

Crop Residues

Rice straw, rice hull, and other straws and stalks of gramineous crops usually have a low nitrogen content, and a fairly high potassium and silica content, with a large amount of fibrous materials or a high C/N ratio (Table 6). As potassium and silica are helpful in improving the resistance of crops to disease and lodging, and fibrous materials are an energy source for soil microorganisms and

Table 5. Total amount of N, P_2O_5 and K_2O in swine, poultry and cattle manure in Taiwan, 1987

	No. head	N	P_2O_5	K_2O
		mt/year		
Swine	7,129,034	46,830	25,258	17,447
Poultry	68,978,000	50,334	88,119	54,093
Cattle	171,759	11,391	7,736	16,171
Total		**108,555**	**121,113**	**87,711**
Equivalent to % annual chemical fertilizer consumption		45.5	173.7	90.1

Source: Yen 1989

Table 6. Result of chemical analysis of crop residues (dry matter basis)

Type of residue	N	P	K	Ca	Mg	SiO_2	Fe	Mn	Zn	Cu	Ni	Cr
	%						ppm					
Rice straw	0.66	0.07	0.93	0.29	0.64	4.9	427	365	67	9	18	8
Rice hull	0.49	0.05	0.49	0.06	0.04	12.7	173	109	36	7	20	12
Corn stalks	0.81	0.15	1.42	0.24	0.30	4.1	186	38	30	7	-	3
Sorghum stalks	0.74	0.10	1.41	0.35	0.28	3.9	260	28	34	10	-	4
Soybean stems	1.42	0.12	1.04	1.30	0.62	2.9	562	35	27	11	-	4
Peanut stems	1.36	0.14	0.96	0.89	0.58	2.5	546	29	20	42	-	3
Peanut hull	0.70	0.12	0.46	0.48	0.15	1.8	388	45	18	10	26	9
Bark	1.33	0.07	0.60	1.44	0.20	1.2	999	259	41	3	3	8

a good material for the improvement of soil physical properties, these materials can be combined with high-nitrogen organic wastes, such as swine and poultry manure, to make a good compost for crops. If they are used to cover the surface of the soil, these materials are good mulches which help maintain a favorable soil moisture content and temperature, and prevent the accumulation of salts or the multiplication of weeds on the soil surface. However, if they are burned to ash, their fiber and carbon will be completely destroyed, and the ash will have little effect on the soil's physical and biological properties, although the inorganic nutrients still remain and the potassium content may even increase to 3-9%. Such ash can be used to dust onto the leaves of crops to prevent diseases and insects, or can be broadcast onto the surface of nursery soil to prevent soilborne diseases.

The stems of leguminous crops usually have a higher nitrogen content than other crop residues, and also contain considerable amounts of phosphorus, potassium, and other secondary and micro-elements, making them a good material for composting and mulching.

Green Manure

Leguminous green manure crops are an important source of natural nitrogen. These crops are grown so that they will fix nitrogen from the air, and are usually incorporated into the soil at the flowering stage, about ten days before the main crop is planted. In extensively cropped areas, green manure crops are of great value to farmers since they reduce fertilizer costs. They played an important role in crop production in Taiwan soon after World War II. In intensively cropped areas, green manure crops may compete for land with the main crop. However, even in areas with very intensive multiple cropping such as Taiwan, some farmers are still growing *Sesbania sesban* or *Crotalaria juncea* as a green manure in summer, and Berseem clover, milk vetch, and rape in the winter fallow season before the main crop of rice, corn, sorghum etc.. The chemical analysis of these green manure crops is shown in Table 7.

Table 7. Results of chemical analysis of green manure crops (dry matter basis)

Crop	N	P	K	Ca	Mg	SiO_2	Fe	Mn	Zn	Cu	Ni	Cr
	%						ppm					
Sesbania sesban	2.06	0.21	1.10	0.80	0.18	-	198	16	24	12	-	-
Crotalaria juncea	1.99	0.23	0.95	0.82	0.16	-	174	18	36	16	-	-
Berseem clover	2.40	0.23	0.85	2.00	0.34	-	358	42	63	11	-	-

Used Mushroom Compost

Compost which has been used to grow mushrooms and then abandoned has become a good source of organic manure in Taiwan in recent years, with the rapid development of the mushroom industry. Such compost consists mainly of sawdust, with some added materials such as limestone, rice bran etc. Used mushroom compost has a low potassium content as a result of leaching losses during the course of mushroom culture, but the content of nitrogen, phosphorus, calcium, and other secondary nutrient elements remains high (Table 8). In addition, its high content of fibrous material is very helpful for the improvement of soil physical properties and biological activity. However, the remnant mycelia in these materials may sometimes have a harmful effect on the roots of some crops. Therefore, it is recommended that used mushroom compost should be combined with a proper amount of high-nitrogen manure such as swine or poultry manure and fermented to kill the mycelia, before it is applied to the soil.

Table 8. Results of chemical analysis of used mushroom compost (dry matter basis)

Sample	N	P	K	Ca	Mg	SiO_2	Fe	Mn	Zn	Cu	Ni	Cr
	%						ppm					
White mushroom compost	0.88	0.22	0.16	2.91	0.40	-	1863	248	78	16	11	27
Shitake compost	0.86	0.39	0.07	2.69	0.13	-	1209	240	60	15	9	18
Jew's ear fungus compost	0.77	0.30	0.07	3.54	0.24	-	1174	219	83	12	10	19
Golden mushroom compost	0.95	0.90	1.00	0.62	0.56	-	1642	270	52	12	8	20

Common Compost

This is the traditional compost usually made by combining carbonaceous materials such as rice straw, corn and sorghum stalks, corn cob, rice hull, and tree leaves, with nitrogenous materials such as cattle, swine and poultry manure, and rice bran, plus a small amount of field soil for fermentation. This is the best organic manure, since it contains reasonable levels of nitrogen, phosphorus, potassium, silica, as well as enough carbon or fibrous material to improve the physico-chemical and biological properties of the soil (Table 9).

Municipal Refuse Compost

Compost made from municipal refuse usually has a fairly low nutrient content compared to common compost, and sometimes has a high content of heavy metals such as copper, chromium, nickel, manganese, zinc, and cadmium (Table 10). However it is still useful in improving soil fertility, provided there are tight controls over its use. Intermittent and light applications are preferable to repeated heavy dumping, which may cause serious soil pollution. A strict classification of domestic refuse in the home before it is handed over to refuse collectors may help prevent the contamination of refuse compost with heavy metals.

Cattle Manure

Cattle manure has a reasonably high content of nitrogen, potassium and fibrous materials. It is a good animal manure, since there are no pollution problems of heavy metals and antibiotics in using it (Table 11). Repeated applications of this manure to the soil can be recommended, but phosphorus should be supplied from other sources in order to make up the shortage of phosphorus in this manure.

Table 9. Results of analysis of common compost from different sources (dry matter basis)

Location of compost sample	N	P	K	Na	Ca	Mg	Fe	Mn	Zn	Cu	Ni	Cr
	%						ppm					
Tatzuen (1) (west central Taiwan)	1.82	0.18	2.26	0.45	3.25	0.84	2348	488	122	16	14	10
Tatzuen (2) (west central Taiwan)	1.65	0.33	2.13	0.41	2.50	0.61	3008	373	81	17	22	8
Erlin (west central Taiwan) (1)	1.20	0.45	1.40	0.26	3.12	0.77	2524	424	68	12	25	9
Erlin (west central Taiwan) (2)	1.68	0.38	1.72	0.17	2.86	0.52	2948	457	79	14	18	12

Table 10. Results of chemical analysis of municipal refuse compost collected in Taichung, west central Taiwan (dry matter basis)

Sample	N	P	K	Ca	Mg	Na	Fe	Mn	Zn	Cu	Ni	Cr	Cd	Pb
	%						ppm							
I	0.11	0.05	0.25	2.01	0.16	0.16	5525	134	115	31	13	825	0.9	47
II	0.20	0.06	0.41	3.04	0.35	0.21	6550	402	243	82	32	134	2.0	45
III	0.35	0.09	0.53	2.92	0.29	0.32	15775	342	238	109	60	163	1.9	68
IV	0.28	0.10	0.48	1.29	0.28	0.30	16850	417	283	217	36	176	1.8	51

Table 11. Results of chemical analysis of animal manure (dry matter basis)

Kinds	N	P	K	Ca	Mg	Na	Fe	Mn	Zn	Cu	Ni	Cr
	%						ppm					
Cattle (1)	1.06	0.52	0.95	1.06	0.86	0.17	5726	344	122	20	-	6
Swine (2)	1.69	1.39	0.76	3.81	0.54	0.22	1692	507	624	510	19	25
Chickens (3)	2.59	3.09	2.46	12.66	0.91	0.69	1758	572	724	80	48	17

(1): Average values of 3 samples collected from 3 locations in Shiu-shwei, Changhua, west central Taiwan
(2): Average values of 5 samples collected from 5 locations in the Changhua area, west central Taiwan
(3): Average values of 4 samples collected from 4 locations in the Changhua area, west central Taiwan

Swine Manure

The nutrient content of swine manure is slightly higher than that of cattle manure, but its higher copper content (Table 11) and lower content of fibrous material discourage repeated, long-term applications of this manure. It is suggested that it is best to dilute this manure by mixing it with rice hull, sawdust, rice straw and similar fibrous materials, and ferment it before use.

Poultry Manure

The nutrient content of poultry manure is usually much higher than that of swine manure (Table 11). However its higher content of zinc and antibiotics, and its lower content of fibrous material, discourage direct applications of fresh poultry manure to the soil. The best way to utilize this manure is to mix it with cattle or swine manure, rice straw, rice hull, sawdust and other fibrous materials, and ferment it thoroughly before use.

Residues From Oil Extraction

Residues from oil seeds after oil extraction generally have a high nitrogen content and a low level of carbonaceous material (Table 12). Liberal applications of this material to the soil may greatly promote the growth of the vegetative parts of the crop. However, crops given such treatment are usually weak, and are easily attacked and damaged by plant pests and environmental stresses. In addition, applying these residues to the soil when they are still fresh often attracts large numbers of soilborne insects, which may also harm the crop. It is therefore best to mix these seed residues left after oil extraction with rice hull, sawdust, mushroom compost, bone meal, oyster shell etc., and fully ferment the compost before use.

Table 12. Results of chemical analysis of residues left after oil extraction from various oil seeds (dry matter basis)

Samples	N	P	K	Na	Ca	Mg	Fe	Mn	Zn	Cu
	%						ppm			
Sesame cake	6.20	0.55	0.58	0.08	2.16	0.68	367	88	135	26
Soybean cake	4.72	0.81	1.37	0.01	0.28	0.31	218	46	49	17
Soybean meal	5.89	0.79	1.60	0.01	0.27	0.30	168	31	45	18
Cottonseed meal	4.47	0.35	1.26	0.14	0.26	0.50	83	17	41	9
Castor bean meal	4.68	0.39	1.03	0.12	0.70	0.56	181	15	105	20
Rapeseed meal	4.55	0.38	1.15	0.17	0.84	0.52	261	61	45	9
Coconut meal	3.12	0.25	1.84	0.20	0.18	0.40	190	69	44	25
Rice bran	1.95	1.91	1.24	0.01	0.14	0.84	188	96	65	10

Residues From Processing Animal Products

The nutrient content of animal residues differs greatly according to the type of residue (Table 13). Animal blood, meat, horn, feet, wool, and feathers can all be used as a source of nitrogen fertilizer, since they all have a very high nitrogen content. Oyster shell and eggshell can be used as a source of calcium, since both have a very high calcium content, and bone meal can be used as a good source of phosphorus fertilizer since it has a very high phosphorus content. However, all of these are very low in potassium. The use of fur meal from the fur industry should be prohibited, since it has a high content of chromium that can easily accumulate in the soil, causing toxicity in crops. Many animal residues are too expensive to be used as fertilizer, but bone meal is widely used to fertilize fruit trees in Taiwan, and farmers feel that the results are acceptable.

Table 13. Results of chemical analysis of residues from processing animal products (dry matter basis)

Samples	N	P	K	Na	Ca	Mg	Fe	Mn	Zn	Cu	Ni	Cr
	%						ppm					
Animal blood	12.6	0.07	0.18	0.08	0.2	0.10	382	1	18	7	-	2
Snail meal	3.9	1.48	0.45	0.85	14.5	0.88	440	133	-	33	-	-
Fur meal	4.5	0.05	0.02	0.81	0.4	0.11	1070	6	15	11	690	18349
Oyster shell	0.2	0.06	0.02	-	20.6	0.45	4800	159	35	15	-	-
Eggshell	1.0	0.09	0.12	0.09	21.8	0.39	27	5	5	6	-	5
Bone meal	4.7	9.60	0.22	0.15	12.3	0.38	82	5	123	6	-	7

TECHNIQUES OF COMPOSTING

Composting is an ancient practice. Traditionally, most compost has been prepared by rotting stable manure, grassy material and night soil. The first important modern advances in composting were made about 40 years ago in India by Sir Albert Howard, a British agronomist. Farmers in the state in India where this compost was formulated used for composting a 1.5 m high layered pile of garbage, night soil, animal manure, sewage sludge, straw, and leaves. The pile was turned twice, and composting was completed after three months. The Itano process, a mechanized method for large quantities of compost, was first described in 1928. Further methods have subsequently been developed.

Traditional Composting in Taiwan

Selection of Site

It is best to compost materials in a compost hut to prevent leaching losses of nutrients during heavy rain. Compost made in a hut usually has a much higher nutrient content than that made outdoors. However, if there is not enough room in the compost hut to make the amount of compost needed, composting can be carried out outdoors under a tree, to avoid strong sunshine, or in any other place where the topography gives good drainage but there is enough water to wet the composting material. After all the material has been piled up, the top of the pile should be covered with soil, and then the whole pile is covered with a 15 cm layer of rice straw or sugarcane leaves. It should then be pressed down under stones or some other heavy objects, and finally covered with a polyethylene sheet or some other kind of shelter, to conserve the moisture and temperature, and prevent rain from falling into the compost.

Preparation of Composting Material

Materials commonly utilized for compost may be divided into two groups, carbonaceous wastes and nitrogenous wastes. The carbonaceous wastes most often used include rice and wheat straw, sawdust, rice hull, sugarcane leaves, peanut stalks, sweet potato stalks, fallen leaves, chopped cornstalks, corncobs, sorghum stalks, hay, shredded paper etc. Nitrogenous wastes include animal manure, oil cake, rice bran, filter cake, green grass clippings, green weeds, vegetable wastes, garbage, digested sewage sludge etc. Soil is usually added to promote fermentation by conserving water, temperature, and nutrients. Recently, some useful microbes have been identified which can be combined with the composting material to accelerate the fermentation process.

Before composting, carbonaceous material such as rice and wheat straw should be sprayed with water (about 30 kg of water per 100 kg of material) and covered with a polyethylene sheet for one or two days. The straw is then cut into lengths of about 24 cm for making into compost. Corn and sorghum stalks should be cut into smaller pieces. Generally, the compost will be ready for use after about three months if this method is used. If the compost is needed for use within a shorter period, the material should be shredded into smaller pieces. Small amounts of calcium cyanamide, and of urea or other nitrogen fertilizers, can be added to promote fermentation if there is not enough nitrogen in the waste, and calcium superphosphate can also be added to prevent the loss of nitrogen from the compost and improve its quality.

Piling of the Composting Material

A low wall of the prepared material is first banked up in a hollow rectangle, and pressed down as tightly as possible. Carbonaceous wastes are then piled inside the rectangle to a height of about 20 cm. Solid nitrogenous wastes are then added on top of the carbonaceous wastes, liquid animal manure added if this is available, and the whole pile stamped down as firmly as possible to a height of about 10 cm. About 6-9 cm of soil is then added on top of the nitrogenous wastes. Carbonaceous wastes, nitrogenous wastes, and soil are again added in turn, layer by layer, until this has been repeated about five times. A little more liquid manure is added to the top of the final layer, which is then covered with 15-18 cm of soil. Finally, the whole pile is covered with sacking or a polyethylene sheet to conserve the moisture and temperature levels, and protect the pile from rain. If the compost is too dry, it is necessary to add some water occasionally:

wastewater from the kitchen is a good source of water for this purpose. If 1.5-2.0% of calcium cyanamide is added at the time of piling, fermentation will proceed more quickly. Adding calcium cyanamide has the following advantages:

- It promotes the activity of soil microbes, thus accelerating the fermentation of the compost.
- It increases the nitrogen content of the compost.
- The lime in the calcium cyanamide neutralizes the organic acid produced during the composting process.
- Calcium cyanamide may kill insects and harmful microbes in the compost.

Generally, calcium cyanamide is first mixed with 5-10 times its volume of fine soil, and this mixture is then added to the composting material layer by layer. If liquid manure cannot be obtained, it can be replaced by calcium cyanamide alone.

Turning the Compost Pile

Turning the compost pile is an important part of the composting process. Two or three weeks after piling, a large proportion of the composting material will have rotted, but some of it will still keep its original form. It is therefore necessary to turn and mix the composting material every two to three weeks, repeating this two or three times during the whole period of composting. Additional water is necessary if the composting material is too dry. Nitrogenous materials such as liquid animal manure or calcium cyanamide should be applied if the fermentation process is proceeding very slowly, and the material on the outside moved to the inner part of the pile. Generally it will take about 100 days from the time composting begins to when the compost is fully mature.

Judging the Maturity of Compost

The maturity of compost may be estimated simply according to the way it looks and feels.

Immature compost

The original color and shape of the composting material, such as rice straw and sugarcane leaves, are still easily identifiable.

Partly matured compost

The composting material has turned to a brownish color, but still retains its original shape, and is not easily crushed when it is rubbed between the fingers.

Mature compost

Most of the material has become moist, soft, and deep brown or black in color.

Output of Compost

Generally, 1,000 kg of rice straw or sugarcane leaves will produce 2,500 kg of immature compost, or 1,500 kg of mature compost: 1 m^3 of compost is about 1,000 kg in weight.

Biochemical and Microbiological Aspects of Composting

Temperature

A rapid rise in temperature occurs as microorganisms multiply in the composting mass. When the temperature rises above 40°C, the "**mesophilic stage**" is replaced by the "**thermophilic stage**" two or three days after piling. Finally, the temperature in the center of the pile stabilizes at around 70°C, and then gradually sinks to the ambient temperature. The transition from mesophilic to thermophilic microorganisms occurs in accordance with this change in temperature. The temperature after 30 days of composting differs according to the materials. Experiments conducted in Taiwan indicated that the maximum temperature at the last repiling was 65°C for pure swine manure, while the temperatures of swine manure mixed with rice straw and with brewery waste were 55°C and 58°C, respectively (Table 14).

Moisture Content

The optimum moisture level is generally 50-60% (w/w). If the moisture content of the compost is below 40%, decomposition will be aerobic but slow. If the moisture content is above 60%, the prevailing air spaces and wet

Table 14. Comparison of stability characteristics of swine manure mixed with rice straw, before and after 30 days of composting

Characters of compost	I Pure swine manure	II Swine manure + rice straw	III	IV	V	VI
			Swine manure + rice straw			
			+ brewery waste	+ *Bacillus*	+ bacteria	+ *Actinomycetes*
Change in temperature	Up (65°C)	Down (55°C)	Down (58°C)	Down (53°C)	Down (60°C)	Down (57°C)
Bulk density	Decreased (0.9-0.6)	Increased (0.6-0.8-0.7)	Increased (0.6-0.8-0.7)	Increased (0.6-0.8-0.8)	Increased (0.6-0.8-0.7)	increased (0.6-0.9-0.9)
Maximum water holding capacity	No signi. diff.	Increased	Increased	Increased	Increased	Increased-not signi.
Nitrogen free extract	Decreased 2/3	Decreased 1/2	Decreased 1/2	Decreased 2/3	Decreased 6/10	Decreased 2/3
Crude fat	Decreased 7/10	Decreased 1/2	Decreased 6/7	Decreased 8/9	Decreased 8/9	Decreased 12/13
Crude fiber	Decreased 1/5	Decreased 1/2	Decreased 1/2	Decreased 1/2	Decreased 1/2	Decreased 3/5
Total N	Decreased 1/10 (7%)	Decreased 1/5 (19%)	Decreased 1/4 (25%)	Decreased 1/5 (19%)	Decreased 1/4 (25%)	Decreased 1/4 (25%)
Soluble N	No signi. diff.	Increased 3.2-decre. 0.6	No signi. diff.	No signi. diff.	No signi. diff.	No signi. diff.
Immobilized N	No signi. diff.	Decreased 1/5 (21%)	Decreased 3/10 (29%)	Decreased 1/5 (19%)	Decreased 3/10 (29%)	Decreased 1/5 (19%)
	(2.0-2.6)	(1.5-2.0)	(1.5-1.9)	(1.3-2.5)	(1.5-2.2)	(1.6-2.5)
C/N ratio	15.0-11.0	21.0-14.0	21.0-14.0	20.0-11.0	20.0-12.5	19.5-11.0
Stability	+	+	+	+++	++	++
Effect of inoculation			Insignificant	Most significant	Significant	Significant

Source: Wang *et al.* 1989, Wang 1989

strength of the material are often insufficient to prevent anaerobic decay. The maximum water holding capacity of the matured compost was increased when rice straw and brewery waste were mixed with pure hog manure.

Aeration and Gaseous Products

A large amount of the organic matter is converted to CO_2 during the course of composting. The concentration of CO_2 can be as high as 18.6% 45 cm below the surface, and as low as 1-2% 72 cm below the surface of the compost heap.

Carbon: Nitrogen Ratio

The relationship between the dry weight of C and the dry weight of N (the C/N ratio) is one of the most important factors in efficient composting. Microorganisms require C for growth and N for protein synthesis. The C/N ratio fell from 15 to 11 after pure swine manure had been composted for 30 days. When rice straw and brewery waste were added, the C/N ratio became higher (21-14), as indicated in Table 14. A C/N ratio of between 26 and 35 is reported by many investigators (Poincelot 1975 etc.) to be favorable for rapid and efficient composting.

Effect of Pollutants

Composting is usually accelerated slightly by the detergents in sewage, and slightly retarded by the oil in municipal refuse, while the herbicides in agricultural residues appear to have no effect (Wesche and Resjinski 1972). The effect of pollutants is therefore quite limited.

Nitrogen Chemistry

The N in plant materials usually starts to change several hours after composting, because compost microorganisms immobilize both inorganic and organic N. The total N in pure swine manure fell by 7% after 30 days of composting. In Group II, to which rice straw had been added, reductions of 19% and 25% were observed. Immobilized N decreased by 21% and 29% in Group II and Group III, respectively, while no significant difference was observed in the pure swine manure (Group I (Table 14).

Microorganisms as Additives

Many aerobic mesophilic bacteria are initially present in the compost and proceed to multiply, but after the temperature has risen due to their increased activity, their numbers may fall again. Thermophilic bacteria initially decompose the protein and non-cellulose carbohydrate components in compost. These bacteria may also attack the lipid and hemicellulose fractions, but cellulose and lignin appear to be able to resist their attack (Poincelot 1955). The addition of imported *Bacillus* TF to a mixture of swine manure and rice straw had a highly significant effect on the rate of composting. The effects of inoculated bacteria and *Actinomycetes* were also significant (Table 14).

Humus and Finished Compost

Polymeric reactions which produce humic acid and humus occur after the compost has cooled down to the ambient temperature. Compost should be "ripened" before it is applied to the soil, otherwise decomposition will continue at the expense of soil N.

APPLICATION OF ORGANIC FERTILIZERS

Compost has the best effect on the physical, chemical, and biological properties of soil when it is applied as a basal fertilizer and fully mixed with the soil. However the timing and placement methods used in application usually vary according to the crop and the type of organic manure.

Timing of Application

Matured organic compost may be applied to the soil at any time during the planting season. For short-term crops such as corn, sorghum, peanut, soybean or some vegetable and ornamental crops, it is usually applied to the soil soon before the crop is sown or planted. However, for long-term crops such as sugarcane, compost is best applied twice in the course of the growing season, once at the planting time and again at the intertillage stage. For perennial crops such as Napier grass, Bermuda grass and fruit trees, compost

is usually applied to the soil soon after the crop is harvested.

The application of immature compost should not generally be encouraged, although some animal manures such as poultry manure are often applied fresh to soil. This must be done at least 15-30 days before planting or seeding of the crop, to prevent the manure having any unfavorable effect on the crop.

Method of Placement

The nature of the crop is the most important factor determining how organic fertilizers are applied.

Broadcasting

This method is usually used on turf and grassland, and in orchards where the ground is covered with pasture grasses. Organic fertilizers are applied to perennial grassland and orchards of this kind without any tillage.

Broadcasting and Plowing Under

This method is suitable for short-term annual crops such as wheat, corn, peanut, soybean, vegetable crops and some flowers. The compost is broadcast and plowed under into the soil just before seeding or planting. A large amount of compost is required to yield significant results when this method is used.

Furrow Application

In this method, the compost is applied in the furrow, directly under or beside the planting row. This method is both effective and economical. The compost is usually applied to row crops at seeding or planting. However for long-term row crops such as sugarcane and sweet potato, and for some perennial crops, a side furrow along the row is often opened with the plow when the crop is at the growing stage, for sidedressing the soil with compost and some chemical fertilizers. This side furrow is then covered over again with the plow.

Hill Application

A large amount of compost is sometimes applied around the base of some long-term or perennial crops such as banana, bamboo, and fruit trees, to promote growth or improve fruit quality. However, only highly carbonaceous compost can be applied in this way.

Hole or Pit Application

This is a very effective and economical way of using compost. The compost is placed in a hole or pit, and mixed with soil before the crop is planted. Peas are usually seeded in a hole filled with organic manure in Taiwan, and young fruit trees are usually planted in a pit with a large amount of compost.

Ditch Application

The compost is applied in a circular ditch or radiating ditches around the base of young fruit trees. The circumference of the ditch system is expanded outwards year by year, until the tree is fully grown.

APPLICATION RATES OF ORGANIC FERTILIZER

The application rate of organic fertilizers is determined mainly by considerations of soil fertility, and the type of crops and organic fertilizer. In general, less than 2% organic matter in the soil is considered to be "insufficient"; 2-5% is "fair", and more than 5% is "plenty". The percentage of organic matter in a given soil can be roughly determined by a visual inspection of soil coloration, as shown in Table 15.

Since the nutrient content of organic fertilizers varies greatly according to the type of organic material, while the nutrient requirement of different crops also varies, selection of organic fertilizers should meet the requirement of the particular crop. Generally, leafy vegetables and other crops of which the vegetative parts are harvested require more nitrogen for better vegetative growth, while fruit trees and fruiting vegetables require less nitrogen and more phosphorus and potassium for better flowering. Therefore, to grow a leafy vegetable such as spinach, the farmer should use poultry manure or some other manure with a high nitrogen content, or combine a higher proportion of high-nitrogen manure with the composting material. For fruiting vege-

Table 15. Identification of % organic matter by inspection of soil color

Unit: % OM

Soil	Brownish yellow reddish yellow light tawny	Light yellowish brown light reddish brown light tawny brown	Brown tawny brown	Dark brown dark tawny brown	Very deep brown blackish brown
Sand	<0.5	0.5-1.0	1.0-2.5	2.5-4.0	>4.0
Sandy loam	<0.7	0.7-1.5	1.5-3.0	3.0-5.0	>5.0
Fine sandy loam	<1.0	1.0-2.0	2.0-4.0	4.0-6.0	>6.0
Loam or silt loam	<1.2	1.2-2.5	2.5-5.0	5.0-7.0	>7.0
Clay loam	1.5	1.5-3.0	3.0-6.0	6.0-8.0	>8.0

Source: Li 1974

tables such as tomato, common compost or other low-nitrogen materials can be used, or low-nitrogen materials such as rice bran or a lower proportion of high-nitrogen manure can be used in the composting material. The recommended rates of compost for various crops in Taiwan, and the commonly used rates of organic manures for crops in Taiwan, are

Table 16. Recommended rates of compost for various crops in Taiwan

Crop	Recommended compost rate
Upland crops	
Wheat, corn, sorghum, sweet potato	10,000-20,000 kg/ha
Tea	20,000-25,000 kg/ha
Tobacco	15,000-20,000 kg/ha
Fruit trees	
Grape	6,000 kg/ha (poultry manure)
	12,000 kg/ha (poultry manure with rice hull)
Wax apple	10 kg/plant
Citrus	10 kg/plant
Starfruit	15 kg/plant (applied when transplanting seedling)
	20-50 kg/plant (adult tree)
Papaya	10,000 kg/ha
Pineapple	15,000 kg/ha
Vegetables	
Leafy vegetables	10,000-20,000 kg/ha
Fruiting vegetables	10,000-20,000 kg/ha
Root vegetables	10,000-30,000 kg/ha
Bulb vegetables	10,000-20,000 kg/ha
Ornamental flowers	10,000-20,000 kg/ha

Source: Tsai 1989

Table 17. Common rates of applying organic fertilizers to crops in Taiwan

Organic fertilizer	Common rates (mt/ha)
Common compost	10-30
Municipal compost	10-20
Cattle manure	10-30
Swine manure	5-10
Poultry manure	2-6
Poultry manure with rice hull	4-12
Soybean meal	1.5-3
Rice hull	10-20
Rice bran	1.5-3
Bonemeal	0.5-1

Source: Tsai 1989

shown in Tables 16 and 17, respectively.

EFFECT OF ORGANIC FERTILIZERS ON CROP PRODUCTION

Applying organic fertilizers to the soil does not necessarily always benefit the crop. Under poorly drained conditions, applied organic matter may intensify the reduced condition of the soil to induce oxygen deficiency in the root area of the crops, or cause toxic gas to form which has a harmful effect on the crop. It is well-known in Taiwan that the application of compost to lowland rice in the Lanyang Plain, on the east coast, often causes a reduction in rice yield because of the poor drainage conditions in the plain. However, under well-drained conditions, organic materials may give benefits which often exceed the contribution of the fertilizer elements alone.

Effect of Green Manure on Crop Yield

An experiment was carried out at the Taichung District Agricultural Experiment Station in west central Taiwan, using Berseem clover, milk vetch, and rape as the green manure, to see their effect on the grain yield of sorghum. After plowing under only one crop of green manure, the soil organic matter content increased slightly (Fig. 1), while the grain yield of sorghum increased proportionally with the amount of green manure (Berseem clover) applied. Fig. 3 shows that the grain yield of sorghum increased about 20% and 45% when 20 and 30 mt/ha of Berseem clover was applied. The pH values of the soil with Berseem clover rose from 4.8 to 5.2 at Nantou (Fig. 2). However, the grain yield from a combined treatment with Berseem clover and lime was much higher than that from the treatment of Berseem clover alone (Fig. 4).

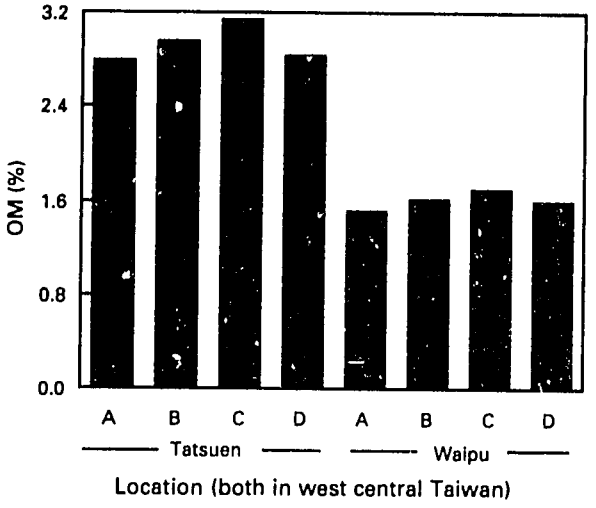

Fig. 1. The soil organic matter content after harvest
A: Control B: Milk vetch
C: Berseem clover D: Rape
Source: Tsai *et al.* 1989

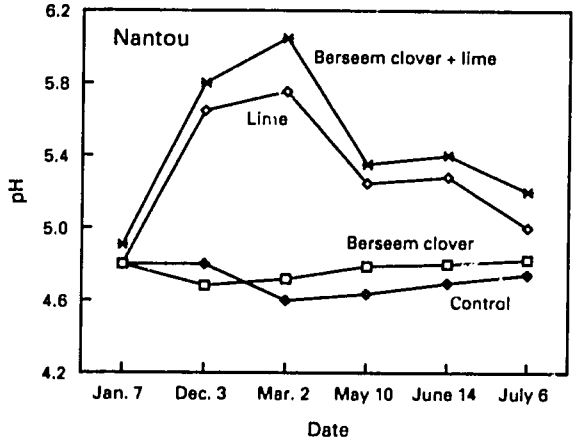

Fig. 2. Effects of Berseem clover with lime treatment on soil pH at Nantou, west central Taiwan
Source: Tsai *et al.* 1989

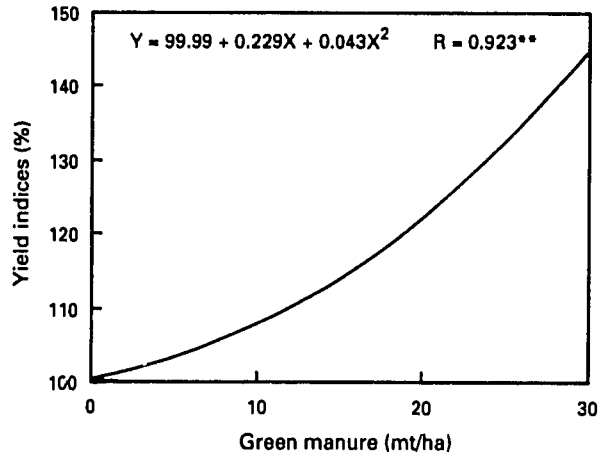

Fig. 3. Relationship between the fresh weight of Berseem clover and the grain yield indices of spring sorghum
Source: Tsai *et al.* 1989

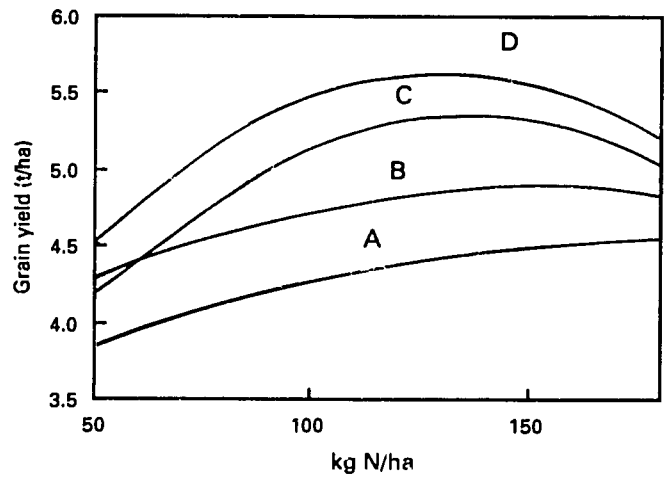

Fig. 4. Relationship between the grain yield of spring sorghum and nitrogen application rates from various treatments

A: Control	$Y = 3.375 + 0.011X - 0.000023X^2$	0.705*
B: Berseem clover	$Y = 3.53 + 0.017X - 0.000052X^2$	0.726*
C: Lime	$Y = 2.282 + 0.045X - 0.000162X^2$	0.678*
D: Berseem clover + Lime	$Y = 2.689 + 0.045X - 0.000169X^2$	0.881**

Source: Tsai *et al.* 1989

Lien (1985) reported that mulching the soil with *Sesbania sesban* increased the grain yield of corn from 3.4 mt/ha to 4.4 mt/ha at a nitrogen level of 60 kg/ha, without tillage, and from 4.4 mt/ha to 4.9 mt/ha at a nitrogen level of 180 kg/ha, without tillage (Fig. 5).

After a series of experiments, Shiue reported that the application of 20-40 mt/ha of crotalaria saved 39-63 kg/ha of fertilizer N for the first crop of sugarcane, and 61-86 kg/ha for the second crop of sugarcane. The residual effect of the two green manure crops on ratoon sugarcane was equivalent to 33-60 kg of fertilizer N.

Effect of Municipal Compost on the Yield of Sugarcane

Municipal refuse compost, if properly utilized, can also be a good organic fertilizer. The result of an experiment at Pintung, southern Taiwan, showed that the yield of sugarcane increased by 11.1 and 24.4% at rates of 20 and 40 mt/ha, respectively, of

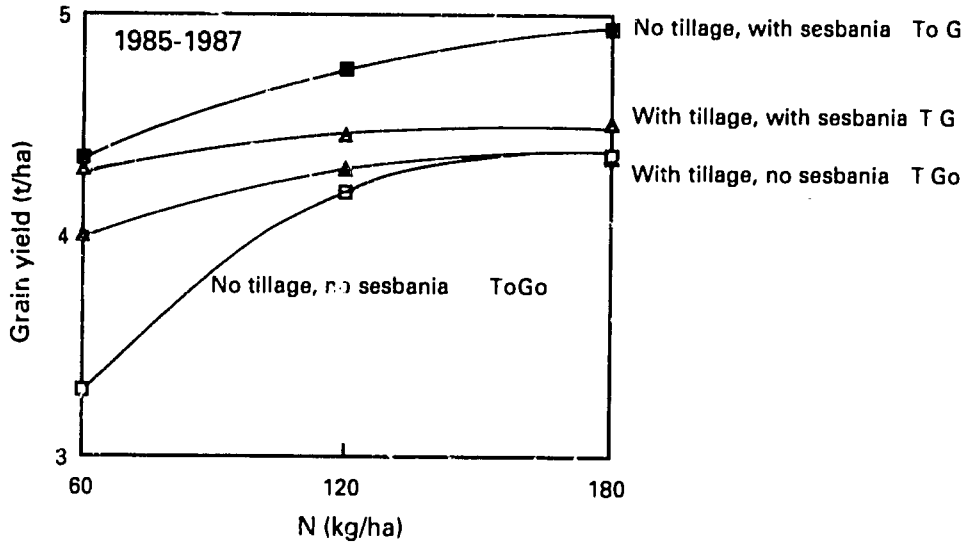

Fig. 5. Effect of interseason cropping of Sesbania and tillage on the yield of corn under rice-corn system (TNG 351, Wu-feng, mean of 1985-1987)
Source: Lien 1985

municipal compost on a sandy loam soil. Increases in yield were 4.8 and 16.9%, respectively, when the same levels of municipal compost were applied to a clay soil (Table 18).

Effect of Common Compost on the Yield of Vegetable Crops

It is well-known that upland crops usually show a better response than paddy rice to organic fertilizer. A good yield response in some vegetable crops to the application of compost under optimal supplies of NPK fertilizer have been reported by several scientists at our experiment station in Taichung. At a rate of 20 mt/ha of compost, the yield of spinach grown on an acid alluvial soil increased by 11-21%. Chinese cabbage and ordinary cabbage both showed a yield increase of 6% on neutral alluvial soil, and potatoes given 15 mt/ha of compost showed a 7-15% yield increase on acid alluvial soils.

Table 18. Effect of municipal compost on sugarcane yield

Amount of compost applied (mt/ha)	Type of soil	Cropping season	Sugarcane variety	Yield (kg/ha)	Index
0 (ck)	sandy loam	autumn	F156	108.02	100.0
20	sandy loam	autumn	F156	120,046	111.1
40	soybean loam	autumn	F156	134,421	124.4
0	clay	spring	F160	77,850	100.0
20	clay	spring	F160	81,580	104.8
40	clay	spring	F160	90,980	116.9

Note: Data from the Shiying (Pingtung) farm of the Taiwan Sugar Company, 1970-1971
Length of growing season of the autumn and spring crops is 18 and 12 months, respectively
Source: Li 1974

CONCLUSIONS

Organic fertilizers are very important for the maintenance and improvement of soil fertility, due to their multiple roles in the improvement of the soil's physico-chemical and biological properties. However no organic material can give the full range of benefits by itself. Some carbonaceous organic materials, such as rice straw, corn stalks, rice hull, sawdust etc., are very useful for improving the physical and biological properties of the soil, but they are also very low in the content of such nutrients as nitrogen, phosphorus and potassium. Some nitrogenous organic materials, such as residues left after oil extraction, swine and poultry manure etc., are high in the nitrogen, phosphorus, and potassium which help to improve the chemical properties of the soil, but they are not very effective in improving its physical properties, since they have a relatively low content of carbonaceous materials. A proper combination of carbonaceous and nitrogenous organic materials to make a mature compost may make these materials into a more effective and complete fertilizer. Furthermore, some organic materials contain harmful mycelia, antibiotics, plant pests, and excessive rates of heavy metals. Proper mixing and composting may greatly improve the quality of organic materials, as a result of the dilution or sterilization effects.

The selection and application rate of organic fertilizers must be based mainly on the fertility conditions of the soil, and the nutrient requirements of individual crops. However, soil treatments using organic fertilizers are only effective under well-drained conditions. Adverse effects from the application of organic fertilizers are not uncommon in poorly drained areas.

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DISCUSSION

Q. (T. Chakraborty)

We are convinced in India that organic farming will be successful, but I should like to draw to your attention to certain problems, particularly in developing countries.

- There are not enough organic materials available in many small farm systems. In countries like India, most farms are small and marginal and 60-70% of the dung and residues the farm produces are used as fuel.
- The mineralization process of organic residues takes time, whether it occurs *in situ* or in a compost heap.
- Only 30-40% of India is irrigated, and there may be a shortage of water for composting during the dry season.
- When we compare organic fertilizers with chemical fertilizers, we are concerned with environmental pollution from residual nutrients. We are also concerned with the high cost of handling and processing organic materials. In one of your experiments, the best results were seen from an application of 40 mt/ha of organic matter. We have similar results in India, but the high handling and processing costs may still make this uneconomic.

A. I think that materials in organic fertilizers need to be balanced. In terms of availability, there are many livestock and poultry in Taiwan, and mushroom growing is very widespread, while there is lots of rice straw, rice hull, and sugarcane tops. If all these residues were collected and utilized, there would be no shortage of materials for organic fertilizers.

In terms of the time required for mineralization, although the traditional method of composting may take up to three months, the addition of *Bacillus* or *Actinomycetes* and crushing or cutting up the composting material can shorten the composting period to 30 days or even less. If you have to use less water in composting, the process will take longer: in all our experiments, at least 50% water (by weight) was needed for rapid composting. If the compost is drier than this, composting will take longer.

Pollution from chemical fertilizers is a common concern, and is the main reason why people want to make increased use of organic fertilizers. However pollutants, especially heavy metals, are also present in materials used for composting.

I agree that the cost of collecting and composting organic materials can be high, but this should be less serious in a country like India, where labor costs are low.