Effect of Organic Amendments and EM on Production of Food Crops in Malaysia

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Abstract

The use of organic amendments as nutrient sources compared with chemical fertilizer was studied. Three trials, one pot and two field experiments, were conducted to evaluate the effects of organic amendments, chicken manure and palm oil mill effluent (POME), on the yields of Chinese cabbage (*Brassica chinensis* L.) and sweet corn (*Zea mays* L.). The organic amendments were applied at a rate of 20 tons ha^{-1} with and without application of Effective Microorganisms (EM 4). An objective was to test the ability of EM 4 to accelerate the mineralization of organic materials and also to evaluate its effect on fertilizer use efficiency. Soils used in these studies were Typic Paleudults.

Results showed that chicken manure improved the yield of Chinese cabbage in the pot study. The yield was further improved when EM 4 was applied under field conditions. However, yields of cabbage grown on the Tebok and Serdang soils and amended with POME (with and without EM 4) were lower than for the chemical fertilizer and chicken manure treatments.

In field experiments, the yield of sweet corn was highest with the chicken manure plus EM 4 treatment, However, the differences between the EM 4 treatments were not significant. Similarly, there were no significant yield differences between chemical fertilizer and POME with and without EM 4, This suggests that in a longer growing period corn would benefit from the mineralization of POME, thus, making it as effective as chemical fertilizer for crop production.

Introduction

Malaysia is basically an agricultural county. It produces rubber, palm oil and cocoa; these raw materials are processed before exportation. One of the by-products of these commodities is a vast amount of agricultural waste. For example, the 6 million tons of crude palm oil that was processed in 1986 generated 11,360,000 tons of waste commonly known as palm oil mill effluent (POME) (Aini and Zahari, 1990).

Although the use of chemical fertilizers in Malaysia is increasing, there is growing concern about the impact of these materials on the economy, human health and the environment. The cost of chemical fertilizers has increased tremendously and their excessive use can be a major cause of environmental pollution. Therefore, at present, agriculture is faced with a dilemma which requires an alternative or a compromise between the use of expensive chemical fertilizers and, at the same time, avoidance of their excessive use. An alternative to chemical fertilizers is to use organic wastes such as animal manures or POME.

If these wastes are discharged into a river or stream they could pose a serious threat to the environment. Alternatively, they can be a cheap source of organic matter and plant nutrients, particularly if they are processed to make field application more practical. Therefore, they need to be effectively and efficiently utilized to ensure optimum crop production, while at the same time, protecting and conserving the environment.

Organic wastes and residues can greatly enhance the chemical, physical and biological properties of soil. Waste products such as POME can be used as an organic fertilizer to provide an abundant supply of plant nutrients, particularly N, P, and S, from its interaction with beneficial soil microorganisms. However, there are also disadvantages to using these materials as fertilizers. First, the release of nutrients from an organic source requires the action of soil microorganisms and can be slow and erratic. Therefore, they must be applied long before the planting season so that the release of nutrients will coincide with the maximum rate of crop growth and nutrient demand. Second, the comparatively low nutrient content of most organic wastes requires large applications to soil to meet the crop's nutrient requirements. Also, waste products may contain human and plant pathogens; heavy metals that pose hazards to human and animal health; and persistent, toxic, synthetic organic chemicals (Sommers and Giordano, 1982).

It was reported that certain mixed microbial cultures or inoculants called Effective Microorganisms (EM) can accelerate the mineralization rate of organic materials and release of plant nutrients (APNAN Newsletter, 1990). EM technology was developed by Professor Teruo Higa, University of the Ryukyus, Okinawa, Japan. The Asia-Pacific Natural Agriculture Network has sponsored research trials since 1990 to determine the effectiveness of EM for releasing nutrients from a number of common organic waste materials to enhance their value and use as biofertilizers in lieu of chemical fertilizers.

As an APNAN participant, studies were initiated in Malaysia to evaluate the utility of EM in combination with different organic waste materials. Three studies were conducted which were extensions of studies reported at the Second APNAN Steering Committee Meeting held in Kuala Lumpur in January 1991. A pot study and two field trials were conducted to evaluate the effectiveness of EM 4 when used with two sources of organic matter, namely chicken manure and POME, on the yield of two food crops, i.e., Chinese cabbage (*Brassica chinensis* L) and sweet corn (*Zea mays* L.).

Materials and Methods

Experiment I: Pot Study With Chinese Cabbage

Soils of the Tebok and Lating series were used in this study. These are important agricultural soils for the south-central and northeast Regions of Peninsular Malaysia, respectively. Soils were sampled in the field at a depth of 0 to 15 cm, air dried, and then ground to pass a 2-mm sieve Their characteristics are shown in Table 1.

Table 1. Chemical Properties of the Tebok and Lating Soils

Properties	Tebok	Lating
pH(H_2O)	4.7	5.0
pH(KCl)	4.0	3.7
Carbon (%)	0.9	2.0
Organic Matter (%)	1.5	3.5
Nitrogen (%)	0.2	0.2
P (mg kg^{-1})	8.4	2.5
K ($cmol^{(+)}$ kg^{-1})	0.6	0.1
Ca ($cmol^{(+)}$ kg^{-1})	0.3	1.4
Mg ($cmol^{(+)}$ kg^{-1})	0.3	0.1
Zn (mg kg^{-1})	1.5	3.2
Fe (mg kg^{-1})	61.3	586
Mn (mg kg^{-1})	5.2	7.3
Cu (mg kg^{-1})	0.1	2.2
CEC ($cmol^{(+)}$ kg^{-1})	12.5	21.4

The design of this experiment was a Completely Randomized Design (CRD) with 4 replicates for each of the eight treatments shown in Table 2. Two kilograms of soil were packed into earthen pots of 35 cm diameter and 25 cm height. For treatments T3 and T4, N-P-K fertilizer was thoroughly mixed into the soil four days prior to planting. For treatments T5 through T8, organic amendments with characteristics shown in Table 3 were incorporated and mixed into the soil two weeks before planting and allowed to decompose. Treatments were duplicated except that a culture of effective microorganisms (EM) was added to one pot of each pair.

Table 2. Treatments Used in the Pot Study with Chinese Cabbage (Experiment 1).

Treatment	Designation	Rate of Fertilizer Applied
Control (+EM)	T1	No fertilizer added
Control (-EM)	T2	No fertilizer added
Chemical fertilizer (+EM)	T3	200 + 90 + 90 kg ha^{-1}
Chemical fertilizer (-EM)	T4	200 + 90 + 90 kg ha^{-1}
Chicken manure (+EM)	T5	20 tons ha^{-1}
Chicken manure (-EM)	T6	20 tons ha^{-1}
POME (+EM)	T7	20 tons ha^{-1}
POME (-EM)	T8	20 tons ha^{-1}

[1]Chemical fertilizers applied were urea, triple superphosphate and muriate of potash, respectively.

Table 3. Composition and Inorganic Fertilizer Equivalent of Organic Amendments Used in the Pot and Field Experiments.

Nutrient	Dry Matter (%)			Fertilizer Equivalent* (kg ton^{-1})	
	Chicken Manure	POME		Chicken Manure	POME
N	2.2	2.0	Urea	49.7	43.5
P_2O_5	3.6	1.4	CIRP	99.0	40.0
K_2O	1.6	0.2	MOP	26.2	2.7
MgO	1.5	3.8	Kieserite	56.5	144.7
CaO	13.6	3.5			
C	29.8	36.2			
C:N	13.3	18.5			
C:P	19.1	57.5			

*CIRP- Christmas Island rock phosphate
MOP- muriate of potash (KCl)

Chinese cabbage (var. Parachinensis) seedlings of approximately equal size were transplanted into the potted soils and allowed to grow until harvest. Water was applied twice a day with a watering can. No agricultural chemicals were used in this study despite some problems with leaf borers during the early stages of growth.

The plants were harvested after 6 weeks. Whole plants from each pot were sampled, placed in paper bags and dried at 60C to a constant weight. The dry weights were recorded for each sample before grinding for chemical analysis.

Experiments 2 and 3: Field trials with Chinese Cabbage and Sweet Corn

Both experiments were conducted at the University of Agriculture Farm. Soils on this farm are dominated by the Serdang series; the chemical characteristics are shown in Table 4.

A Randomized Complete Block Design (RCBD) with 4 replications of each treatment was used for both experiments. The details and plot sizes for the experiments are shown in Table 5. The timing of the fertilizer application for all treatments is similar to that of Experiment 1. EM was applied to one-half of the plots. Chinese cabbage was harvested after 6 weeks of growth. Samples were collected from the middle row and dry-weight yields were determined as in Experiment 1.

Nutrient uptake by sweet corm was determined from the ear leaves harvested from the two middle rows of each block at the tasseling stage. Fresh cobs and stover were similarly sampled for each plot after 72 days of growth.

Table 4. Chemical Properties of the Serdang Soil Series.

Properties	Values
pH(H_2O)	5.0
pH(KCl)	4.2
Carbon (%)	1.4
Organic Matter (%)	2.3
Nitrogen (%)	0.2
P (mg kg^{-1})	13.0
K ($cmol^{(+)}$ kg^{-1})	0.5
Ca ($cmol^{(+)}$ kg^{-1})	0.3
Mg ($cmol^{(+)}$ kg^{-1})	1.8
CEC ($cmol^{(+)}$ kg^{-1})	6.7

Table 5. Plot Size and Treatments For Field Trials With Chinese Cabbage and Sweet Corn (Experiments 2 and 3).

Experiment	Crop	Plot size (m x m)	Plant Density/plot
2	Chinese cabbage	1.0 x 5.4	120
3	Sweet corn	6.0 x 4.0	72

Treatments[1]	Designation	Rate of Fertilizer Applied[2]
Control (+EM)	T1	No fertilizer added
Control (-EM)	T2	No fertilizer added
Chemical fertilizer (+EM)	T3	150 kg N + 150 kg P_2O_5 + 150 kg K_2O ha^{-1}
Chemical fertilizer (-EM)	T4	150 kg N + 150 kg P_2O_5 + 150 kg K_2O ha^{-1}
Chicken manure (+EM)	T5	20 tons ha^{-1}
Chicken manure (-EM)	T6	20 tons ha^{-1}
POME (+EM)	T7	20 tons ha^{-1}
POME (-EM)	T8	20 tons ha^{-1}

[1] Control treatments (T1 and T2) were not assigned to Experiment 2 because of the limited plot space available, and because results have consistently shown that very low crop yields are obtained without application of chemical fertilizers or organic amendments.

[2] Split applications of chemical fertilizer were applied; one-half applied 4 days prior to planting both crops and the other half applied 3 weeks after planting Chinese cabbage and 5 weeks after planting sweet corn. Treatments designated as T3 and T4 both received the total N-P-K rates per hectare as indicated.

Preparation and Application of EM 4

EM 4 was prepared from EM 2 stock one day prior to use; the EM 2 stock was procured through Professor Teruo Higa at the University of the Ryukyus, Okinawa, Japan. To prepare EM 4, 10 ml of EM 2 stock was cultured in one liter of an aqueous solution containing 20 g molasses and 0.5 g urea. The culture was then stirred intermittently for 2 to 3 minutes and shaken at 4-hour intervals for 24 hours. The solution was stored at 5C before use.

The EM 4 was used to treat seeds and soils at various stages of the experiment as shown in Table 6. EM 4 was hand-sprayed on the surface of the soil. A lower concentration of EM 4 was applied again one week later to ensure that the population of microorganisms was maintained.

Table 6. Rate and Time of Application of EM 4 for All Experiments.

Experiment	Rate	Time of Application
1	12 ml pot^{-1}	1 week prior to planting
	1 ml pot^{-1}	1 week after germination
2 and 3	25 ml pot^{-1}	1 week prior to planting
	15 ml pot^{-1}	1 week after germination
	10 ml pot^{-1}	1 week thereafter

Results and Discussion

Experiment 1: Pot Study with Chinese Cabbage

Dry matter yields and nutrient content of Chinese cabbage resulting from the various treatments are shown in Tables 7 and 8. The dry matter yields from the fertilizer treatments showed signifcant increases with or without EM 4 application. The chicken manure treatments (T5 and T6) gave the highest yield for both EM concentrations but no significant effect of EM 4 was detected. The POME treatments (T7 and T8) with and without EM produced the lowest yields except for the controls. These results are best attributed to the differences in fertilizer value of the two amendments, i.e., chicken manure had a considerably higher nutrient content compared with POME (Table 3). Because of the relatively high C:N ratio of POME, it is possible that some N was immobilized and remained unavailable for plant uptake which could have limited crop growth and yield. As recommended, POME should be mixed with the soil at least 4 to 6 weeks before planting to ensure mineralization and nutrient availability (Gunnit *et al.*, 1989). However, with the addition of EM 4 (T7) to the Lating soil, two weeks was sufficient to achieve the release of nutrients from the POME treatment.

Table 7. Yield and Nutrient Content of Chinese Cabbage as Affected by Fertilizer and EM 4 in the Tebok Soil Series[1].

Treatment	Dry Matter ($g\ pot^{-1}$)	N (%)	P (%)	K (%)	Ca (%)	Mg (%)
T1	0.5d	2.5f	0.4b	1.1d	2.2b	0.1b
T2	0.5d	2.4f	0.3c	1.1d	2.2b	0.1b
T3	4.8a	4.5b	0.5a	4.1a	2.2b	0.2a
T4	4.1b	3.2e	0.5a	3.9a	2.1b	0.2a
T5	5.4a	5.5a	0.5a	4.1a	2.8a	0.2a
T6	5.0a	3.4d	0.4b	3.5b	2.7a	0.2a
T7	1.3c	4.3c	0.4b	3.4b	2.4b	0.2a
T8	1.3c	3.2e	0.3c	1.7c	2.2b	0.2a

[1] Column means followed by a common letter are not significantly different at the 5% level of probability.

Table 8. Yield and Nutrient Content of Chinese Cabbage as Affected by Fertilizer and EM 4 in the Latin Soil[1].

Treatment	Dry Matter ($g\ pot^{-1}$)	N (%)	P (%)	K (%)	Ca (%)	Mg (%)
T1	1.0b	2.6d	0.4a	0.7f	2.2c	0.2a
T2	0.8b	2.6d	0.3b	0.9f	2.1cd	0.1b
T3	6.1a	4.4b	0.4a	3.9c	2.1cd	0.2a
T4	5.0a	3.0d	0.3b	3.4d	2.0d	0.2a
T5	6.8a	5.1a	0.4a	5.5a	2.6a	0.2a
T6	6.2a	3.6c	0.3b	4.3b	2.6a	0.2a
T7	4.4a	4.4b	0.4a	3.6cd	2.4b	0.2a
T8	2.2b	2.7d	0.3b	2.6e	2.1cd	0.2a

[1] Column means followed by a common letter are not significantly different at the 5% level of probability.

From this experiment, it is apparent that EM 4 was beneficial to the POME treatments (T7 and T8). A significant increase in yield was detected when EM 4 was applied with the POME treatments to the Lating soil.

Experiment 2: Field Trial with Chinese Cabbage

Dry matter yield and the nutrient content of Chinese cabbage grown under field conditions are shown in Table 9. Results were similar to that of Experiment 1, i.e., chicken manure supported the highest yields and nutrient uptake, followed by chemical fertilizer and POME treatments.

The effect of EM 4 on dry matter yield of Chinese cabbage was observed only with the chicken manure treatment. The increase in dry matter yield with chicken manure and EM 4 (T5) was statistically significant compared to that obtained without EM 4 (T6). A possible explanation for this result may be the time that was required for these two organic amendments to become mineralized in soil and their nutrients available for plant uptake. Because of its higher C:N ratio (18.5) compared with chicken manure (13.3), the 2-week equilibration period after soil incorporation may not have been sufficient for POME to become completely mineralized by the micro-organisms in EM 4. Thus, its effect was not significantly different from that of the untreated POME. This confirms the report that POME has to be incorporated into the soil at least 4 to 6 weeks prior to planting (Gurrnit *et al*., 1989).

The N and P contribution to dry matter yield was greatest for chicken manure applied with EM. There were also significant differences between the chemical fertilizer and POME treatments. The content of K, Ca and Mg in the plant tissues did not show any significant differences be between treatments. A possible explanation for this may be that the nutrient contribution of organic materials is generally N and P.

Table 9. Yield and Nutrient Content of Chinese Cabbage as Affected by Fertilizers and EM in the Serdang Soil[1].

Treatment	Fresh Wt. (kg/ha)	N (%)	P (%)	K (%)	Ca (%)	Mg (%)
T3	5333b	2.1bc	0.3b	2.2b	0.3ab	0.2a
T4	4833b	1.8c	0.3b	2.1b	0.3ab	0.2a
T5	8306a	2.2b	0.4a	3.0a	0.4a	0.2a
T6	4971b	2.5a	0.4a	2.6ab	0.4a	0.2a
T7	3111c	1.9c	0.3b	2.5ab	0.3ab	0.2a
T8	3028c	1.7d	0.2b	2.7ab	0.4a	0.2a

[1] Column means followed by a common letter are not significantly different at the 5% level of probability.

Experiment 3: Field Trial With Sweet Corn

Results of this experiment were similar to those using the same site and layout that was disclosed at an earlier APNAN Steering Committee meeting. Chicken manure, chemical fertilizer and control treatments were applied to plots on the same site. In this experiment POME was used as a substitute for the goat manure that was used earlier and the POME treatments were assigned to the same plots. The previous experiment clearly showed that inorganic chemical fertilizer was superior to that of the organic fertilizers. However, in this experiment, the results showed that despite the superior effect of chicken manure compared with the other treatments, no significant differences were detected among the treatments for any of the parameters studied. In terms of their nutrient supplying capability, all fertilizer sources were equally effective in providing N, P, K, Ca, and Mg to the crop. There were no clear effects of EM 4 in any of the treatments. The implication was that the organic amendments used were as effective as chemical fertilizers in supplying nutrients for the growth and yield of crops, with or without EM 4 treatment.

A possible explanation for the lack of significance among treatments could be that Experiment 3 used the same site and field layout that had been used two months earlier. The organic amendments applied earlier may have become stabilized with repeated applications, and the nutrients fully available for plant uptake; thus, there would be little difference compared with chemical fertilizer. Another reason for lack of any significant differences is that the entire area had been treated with EM 4 in a previous experiment which may have confounded the present experiment.

These results suggest that the rate of organic amendment applications to soil might be reduced after several cropping seasons if the organic matter content of the soil becomes stable.

Table 10. Yield and Nutrient Content of Sweet Corn as Affected by Fertilizer and EM 4 in the Serdan Soil Series[1].

Treatment	Cob Yield (kg ha^{-1})	Stover Yield (kg ha^{-1})	N (%)	P (%)	K (%)	Ca (%)	Mg (%)
T1	6742ab	11,318ab	2.5a	0.3a	4.0ab	0.9ab	0.2a
T2	6363b	10,313b	1.7b	0.2a	3.6ab	0.8ab	0.2a
T3	7726ab	12,368ab	1.9ab	0.3a	3.3b	1.0a	0.2a
T4	7500ab	12,313ab	1.9ab	0.3a	4.1ab	1.0a	0.2a
T5	8026a	13,601a	2.1ab	0.3a	4.7a	1.0a	0.2a
T6	7188ab	11,546ab	1.9ab	0.3a	3.8ab	0.8ab	0.2a
T7	7367ab	11,747ab	1.9ab	0.3a	4.7a	1.0a	0.2a
T8	7346ab	12,226ab	1.8b	0.3a	3.1b	1.0a	0.2a

[1] Column means followed by a common letter are not significantly different at the 5% level of probability.

Conclusions

The use of organic amendments and effective microorganisms (EM 4) for food crop production in Malaysia was studied in pot and field experiments. From these studies, it was found that organic amendments, i.e., POME and chicken manure, can be used as alternatives to chemical fertilizers in sustaining agricultural production. The effectiveness of using organic materials as fertilizers was further improved with the addition of EM 4 which accelerates the decomposition (i.e., mineralization) of organic amendments and releases nutrients for plant growth.

References

Aini, Z., and A. B. Zahari. 1990. Potential in using industrial waste in agriculture. Report of the FAO Expert Consultation of Asian Network on Bio and Organic Fertilizer. Bangkok, Thailand.

APNAN Newsletter. ISSN 0858-1363 Vol. 1, 1990.

Gurmit, S., S. Manoharan, and T. T. San. 1989. United Plantations' approach to palm oil mill by-product management and utilization. p. 225-234. In Proc. PORIM International. Palm Oil Development Conf. Kuala Lumpur, Malaysia.

Sommers, L. E., and P. M. Giordano. 1982. Use of nitrogen from agricultural, industrial and municipal waste. p. 207-220. In R. D. Hauck (ed.) Nitrogen in Crop Production. American Society Agronomy, Madison, Wisconsin, USA.