SOIL-ENHANCING TECHNOLOGIES FOR IMPROVING CROP PRODUCTIVITY IN MALAYSIA AND CONSIDERATIONS FOR THEIR USE

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Abstract

High usage of fertilizers has led to non-sustainability in crop growth and productivity. Coupled with this, concern for the environment and spiraling petroleum prices have led farmers to revert to cheaper and safer alternatives for crop production. One alternative is the use of soil enhancers in the form of composts, indigenous microbes (IMO) and enzymes from natural farming technology, effective microbes (EM) and arbuscular mycorrhizzal fungi (AMF). Increased plant growth, weight and sizes of plants using these soil-enhancing technologies have been reported in several states in Malaysia. Moreover, farmers claim that vegetables taste sweeter, are crispier and have shinier skins than conventionally grown vegetables. The use of AMF is largely confined to the oil palm sector in increasing growth, particularly at the nursery stages. AMF also has a prophylactic effect on oil palms stricken with the soft rot fungi, Ganoderma. *However, several considerations such as improving the inoculum quality, research needs and usage protocols need to be addressed to further advocate the use of these soil-enhancing technologies in Malaysia.*

Introduction

Changes in agriculture policies started around 1960 in Malaysia during the green revolution, inducing farmers to be fully dependent on chemical fertilizers for plant growth. For vegetable farmers, prior to the 1960s, night soil was the main source of fertilizer. However, diseases such as typhoid, and human parasites such as enteric worms were common and prevalent during that time. The Government of Malaysia therefore halted its use to curb the transmission of disease. Subsequently, chemicals started to enter the market and to date the use of chemical fertilizers remains popular. However nowadays, factors such as soil degradation, chemical pollution, the demand for safe food and more importantly, the rising cost of petroleum have forced farmers to seek other alternatives. The role of micro-organisms in building up soil nutrients has often been ignored and a “living soil” is the ultimate goal. Soil enhancers include composts, microbial inoculants and enzyme preparations used for enriching the soil. The usage of chemical fertilizer, the present scenario and some of the soil-enhancing technologies used in Malaysia for improving crop productivity are presented in this paper. The use of Natural Farming is emphasized as this is an area promoted by the Department of Agriculture through its extension programme. In order to popularize the use of soil-enhancing technologies to enable Malaysia to decrease chemical fertilizer usage, several issues need to be considered and these issues are also discussed in this paper.

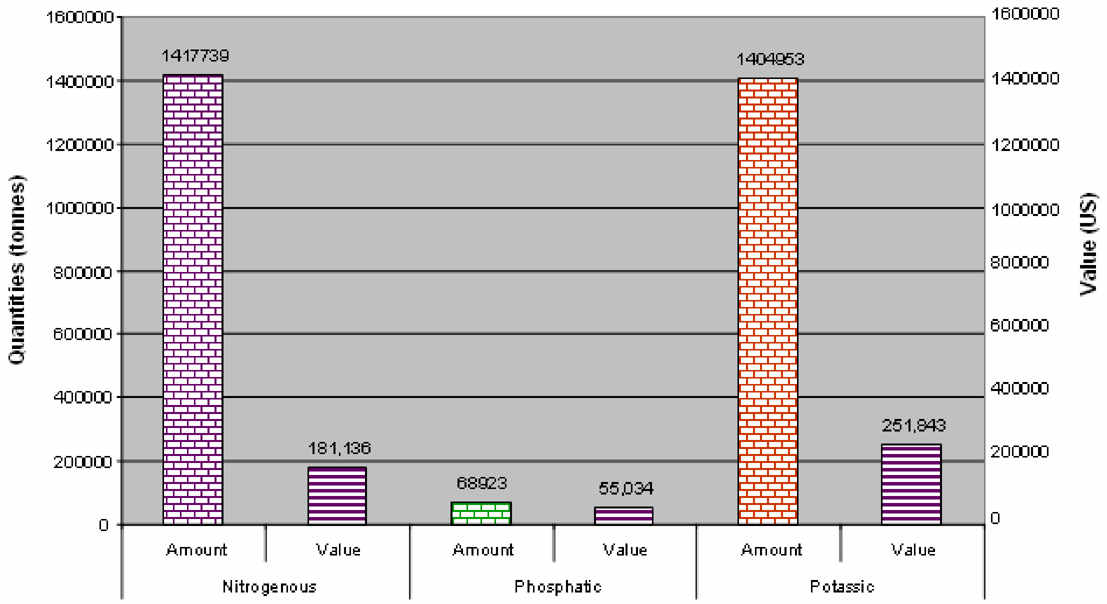
Keywords : soil enhancer, compost, IMO, EM, AMF

Chemical fertilizer usage in the ASEAN region

Total N, P, K consumption in 2002/2003 was 8.98 million tonnes. The average percent ratio of N, P_2O_5 and K_2O used in comprehensive fertilizer formulation during the period of review was 57.8:19.4:22.8. A higher portion of potassic nutrient is used in this region compared to other regions of the world. This is due to the large area of oil palm grown in Malaysia and Indonesia.

In Malaysia, 3.8 million tonnes of N, P, K fertilizers were imported in 2004, valued at US$529 million (Figure 1). Urea, ammonium sulphate and ammonium nitrate are the main nitrogen fertilizers. Malaysia produces high quality (prilled) urea compared to the quality of imports. The prilled urea is mostly exported instead and Australia and Thailand are the two largest importers. Urea remains the cheapest N-source and is largely used in paddy and vegetable cultivation. The main types of phosphorus fertilizers are rock phosphate, ammonium and superphosphate. Potassium chloride constitutes the main bulk of potassic fertilizer used. In view of the current oil price hike, the value of imports is expected to increase, especially in 2006.

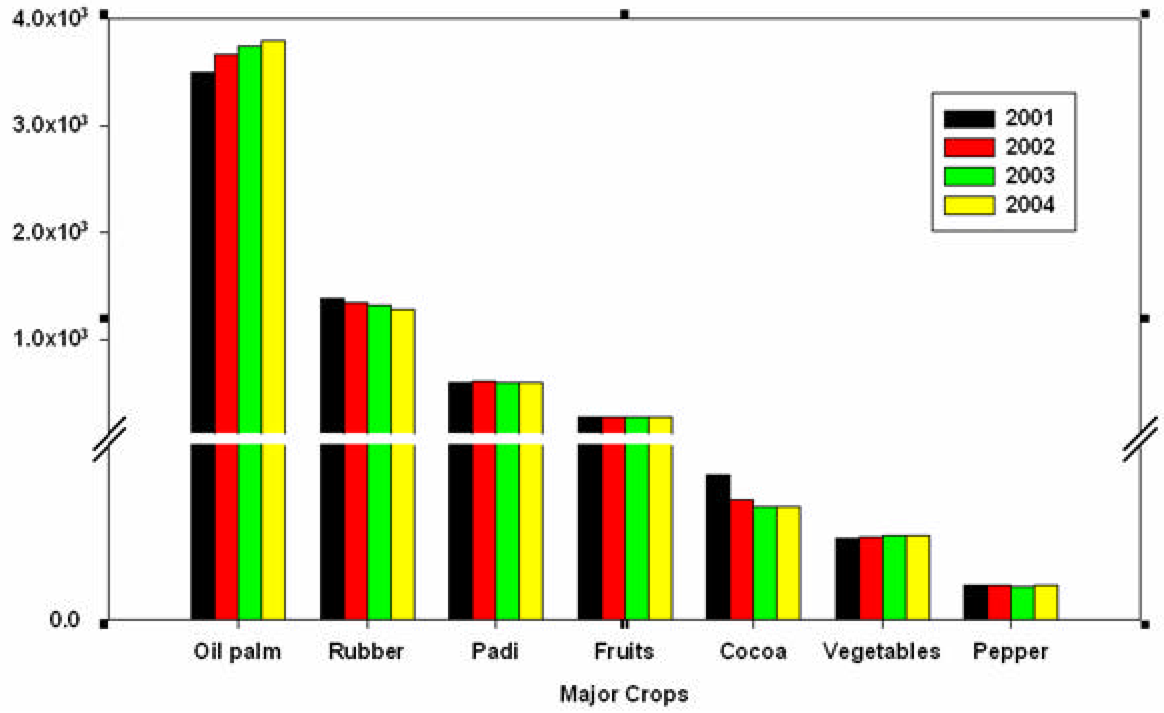
Figure1. Quantities (tonnes) and value (US,000) of Malaysian fertilizer imports in 2004



Source: Anon, 2006

The use of chemical fertilizer is on par with the growing area of crops grown in Malaysia. Oil palm is the most widely grown crop (3.8 million hectares) and this area has increased owing to the escalation in oil palm prices over four years. The area for cocoa has decreased considerably whilst other crops have remained more or less constant (Figure 2.)

Fig.2 Area of six major crops in Malaysia from 2001-2004



Source: Anon, 2006

Organic fertilizers and composts as soil enhancers

Import of organic fertilizer stands at 6,000 tonnes, valued at US$1.88 million. This figure does not reflect usage of organic fertilizers in Malaysia. Malaysia has an abundance of agricultural wastes that can be turned into composts. In 2000, it was estimated that 32 companies in Malaysia were producing compost but production figures are not available.

It is estimated that the chicken industry in Malaysia generates at least 2,800 tonnes of total solids per day. Most of the chicken dung has been sold cheaply to farmers in its raw form. But nowadays farmers prefer processed chicken dung to mitigate the presence of flies and unpleasant odour. In large chicken farms, especially for layers, the chicken dung undergoes composting within the factory itself. The factory sells the compost at US$80 to 119 per tonne. Some producers also add sawdust, soybean wastes, rice hull, microbial inoculants and enzymes to hasten the composting process. Production ranges from 800 to 2,000 tonnes annually for these farms. These fertilizers are greatly in demand, especially by vegetable and fruit farmers. In terms of percentages, the chicken dung compost has N, P, K, percentage values ranging between 2.0 and 3.0. Calcium content in chicken dung is high and for vegetable farmers this nutrient is needed in the cultivation of vegetables (Table 1).

Waste generated by other crops such as oil palm, paddy and coconut are also made into compost. Compared to chicken dung, these composts take much longer to mature. Chicken dung manure matures in 60 days whereas the others range between 90 to 150 days. This is attributable to the high C: N ratio of these wastes (Table 1). Though sawdust is also found in abundance, its use is restricted as heavy metal contents are a concern.

Table 1. Nutrient content of some agricultural wastes in Malaysia

Type of wastes	**Nutrient (%) per dry weight basis**					
	N	**P**	**K**	**Ca**	**Mg**	**C:N ratio**
Coconut coir dust	0.39	0.06	1.76	0.13	0.11	117.0
Rice hull	0.40	0.05	0.38	0.07	0.04	102.0
Rice straw	0.53	0.27	1.70	0.50	0.48	67.0
Pineapple trunks	1.18	0.08	2.26	0.09	0.10	37.0
Maize stalks	1.13	0.44	1.75	0.37	0.18	43.0
Oil palm fronds	0.70	0.07	0.97	0.53	0.14	61.0
Oil palm (empty bunch)	0.60	0.06	1.92	0.13	0.11	83.0
Chicken dung	1.72	1.82	2.18	9.23	0.86	12.42
Cow dung	2.05	0.76	0.82	1.29	0.48	30.25
Cocoa pods	1.00	0.05	1.08	0.12	0.05	na

na: not available

Source: Aini *et al*. 2005

The nutrient content also differs, depending on the composition of the materials used. Most compost producers mix about 30% of animal manure into materials with a higher C: N ratio. Weighing the materials is rather difficult due to their bulk; therefore, producers add material by volume instead. This often gives varying results in the compost analysis as the moisture content is not taken into account. The type of materials used is not consistent and they are also taken from different sources; this leads to differences in the nutrient content of the compost (Table 2.). Compost producers must take into account the logistics of the waste materials before deciding on the location to produce the compost. If the waste materials are located at a distance, the cost of the compost will ultimately be dearer. In Malaysia, the most common base materials used for compost are oil palm bunches or palm press fibre as they are easily available and can be collected from the oil palm mills. Others, such as rice hull can be found in mills in the granary areas of northern Malaysia. Rice straw is mostly burnt and not easy to collect. Rice straw is also not popular for compost because the pile decreases to more than 60% of the original size upon maturing. Difficulty in overturning rice straw is another factor as the straw is long and tends to stick as a bundle.

Table 2. Composts from various agricultural wastes

Types of materials and their ratios	**Nutrient values (%)**					**pH**	**Final C:N ratio**
	N	**P**	**K**	**Ca**	**Mg**		
Rice hull: chicken dung: burnt hull 1 : 1 : 0.01	0.95	1.53	1.53	5.9	0.58	7.9	24
Coconut coir dust: chicken dung: burnt hull 0.7 : 1 : 0.01	2.32	2.08	3.12	7.92	0.89	8.4	12
Oil palm frond: chicken dung: burnt hull 1 : 1 : 0.01	2.01	1.44	2.34	5.90	0.67	8.6	13
Rice straw: chicken dung: rice bran: spent molasses from alcohol factory 3.6 : 1 : 0.15 : 1	1.57	0.77	2.83	-	-	8.0	15.6
Pineapple trunk: oil palm frond: chicken dung 1 : 1 : 0.4	1.51	1.82	2.79	9.99	0.99	-	13.6

Source: Aini & Vimala 2002

The advantages of composts are:

? They store and release nutrients slowly; thus nutrients are taken up more effectively by the plants.
? Organic matter is increased; as such the root structures, especially the root hairs of the plants are increased.
? They balance the soil pH by acting as a buffer.
? Through recycling wastes into compost, the environment becomes more sustainable.
? They attract earthworms and soil organisms that make the soil a “living” soil.
? They reduce soil erosion.
? They suppress certain soil-borne diseases (Hoitink *et al.* 1997).
? They reduce reliance on petroleum-based fertilizers.

Soil enhancers in the form of microbial inoculants

The soil rhizosphere is the platform for activity. It supports a complex community of micro-organisms that range from beneficial to pathogenic. The plane contains decomposed materials which upon microbial action, release a myriad of chemicals and enzymes essential for plant growth. The fascinating world of the rhizosphere and single-celled microbial life-forms was revealed in the 17th century by Antony van Leeuwenhock. Microbial functions in the rhizosphere were only discovered in 1888 by Martinus Beijerinck, the pioneer of soil microbiology. He discovered the activity of *Rhizobium*, the N-fixing bacteria. The nitrogen cycle was then established with the concomitant functions of microbes responsible for the fixation and release of nitrogen from the air and into the soil. Later, the beneficial functions of other microbes were understood — Arbuscular mychorhizzal fungi (AMF), *Pseudomonas*, *Azospirillium* and many others for nutrient uptake in the soil; *Trichoderma* for combating disease; and *Penicillium* and *Streptomyces* as microbes for producing antibiotics.

With more and more beneficial microbes being discovered, humans began to produce them on a commercial basis to aid nutrient uptake and to combat disease naturally. The advent of chemicals particularly pesticides, herbicides and to a certain extent, the prolonged use of chemical fertilizers have degraded soil as the chemicals kill these living organisms. As such, attempts have been made to enrich the soil with microbes in order to rejuvenate the soil. This is done by introducing microbes such as *Rhizobium*, AMF, *Trichoderma* and others in the form of mixed cultures through microbial inoculants directly or indirectly through composts.

In Malaysia there are many microbial inoculants on the market. Most of the microbial inoculants are imported and only a few are made locally. Imported inoculants have to undergo stringent quarantine procedures by the Department of Agriculture before being employed by farmers. However, a number of technologies related to soil enhancers being used are available and they are worth mentioning. The Natural Farming technology introduced by Korea is being mooted by the Department of Agriculture in various states of Malaysia. This technology makes use of indigenous micro-organisms (IMO) and various homemade preparations to boost soil fertility. Another technology brought from Japan is effective microbes (EM), currently practised in the southern states of Malaysia. Besides its use for enhancing soil fertility, it is more popular in livestock management for its odour-removing properties. A local company — Malaysian Agri Hi Tech — is active in promoting the use of AMF, particularly in the oil palm industry and the same company is also producing *Trichoderma* to control the soft rot fungus, *Ganoderma*.

Use of Indigenous Micro-organisms (IMO) in Natural Farming

The use of IMO as a soil enhancer was started in Malaysia by the Department of Agriculture in 2001 through the Asian Productivity Organization. Farmers in at least three states are actively using this technology. Some farmers claim that this technology decreases the cost of production by 30% compared to conventional practice. However, this technology needs meticulous preparation. Without good training, it is difficult to follow via textbook instructions. The principle needs to be understood before one can grasp the methodology. After familiarization with the techniques, farmers often make changes in the preparations to suit their particular inputs and problems faced.

The basic preparation for enhancing the soil is:

i) IMO4. Indigenous micro-organisms are naturally inoculated by placing cooked rice under a tree in an undisturbed area. Between 3 and 5 days, the rice will turn mouldy (IMO1). Add brown sugar (1:1 ratio) to the mouldy rice and then further ferment for 3-5 days (IMO2). Add the fermented mixture (1gm/L) to 10 kg rice bran and further ferment for 3-5 days (IMO3). This final fermented mixture of rice bran is mixed with the farm soil in the ratio of 1:1(IMO4).

ii) Compost. Add IMO4 at the rate of 1:10 to oil palm empty bunches and compost it for about 3 months.

iii) Fermented plant juice extract (FPJ). Add a volume ratio of 1:1 water spinach (*Ipomoea aquatica*) and brown sugar and leave in a jar for 5-7 days. Cover the jar with white paper and tie the mouth tightly with a string or rubber band.

iv) Fermented Fruit Juice (FFJ). Add chopped papaya (*Carica papaya*) and mix with brown sugar at a ratio of 1:1 by volume and keep in a jar for a week. Cover as in (iii).

v) Oriental Herb Nutrient (OHN). Add cinnamon with rice vinegar at a ratio of 1:3 by volume. Top up with brown sugar at a volume of 1:1 of the mixture of the latter. Leave the mixture to degrade for 7-10 days in a jar before use. Cover as in (iii).

vi) Fish Amino Acid (FAA). Mix fish heads, bones and entrails with brown sugar at a ratio of 1:1 volume and keep in a jar for 1 month. Cover as in (iii).

vii) Egg calcium phosphate (CaP). Burn egg shells and then mix with rice vinegar at a volume ratio of 1:10. Leave to degrade for 30 days.

viii) Bone calcium phosphate PCa. The procedure is similar to (vii) but use cattle bones instead. (Cho 1997)

In field preparation, IMO4 is added at the rate of 1 tonne/ha, four days before planting. Different combinations of the basic formulation are applied to the soil to enhance plant growth. The formulations known as Type II, Type III and Morning Sickness are given in Figure 3. Type II formulation is used during the growth stages of the plant. Type III is used for increasing fruit size and Morning Sickness is for flower initiation and fruit setting. For leafy vegetables, after IMO4 application and when the plant is 5 days old, Type II is sprayed every 5 days at 2% concentration onto the soil; 100 L of Type II at 2% concentration should be sprayed onto the leafy vegetables and the amount is increased by half after 14 days of age.

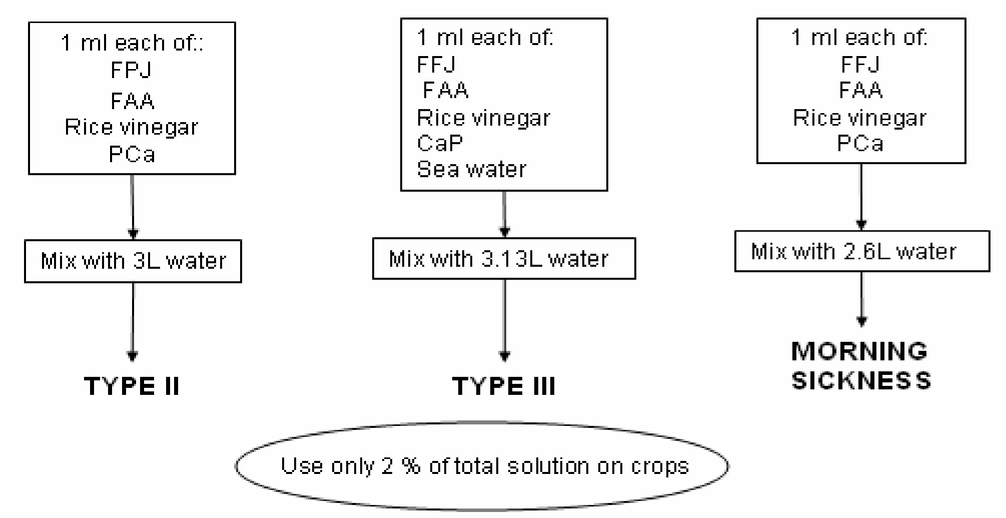


Fig. 3. Formulation of sprays from basic preparation used for different stages of plant growth

For fruit vegetables and fruit trees, Type II, III and Morning Sickness are applied throughout the growth of the plant. Type II is sprayed onto the soil throughout the plant growth with 100 L of 2% concentration. Morning Sickness is sprayed at the onset of flowering and for every 20 days in the case of fruit vegetables. Type III is sprayed when the plant has started to bear fruits and sprayed every 20 days thereafter throughout the plant life. An example of the fertilizer schedule for fruit vegetables is given in Table 3. For seasonal fruit trees like durian (*Durio* sp.), rambutan (*Nephellium lappaceum*) and duku (*Lansium domesticum*), Type II is sprayed every 14 days; at the onset of flowering, Morning Sickness is sprayed. Type III and Morning Sickness is sprayed alternately for every 14 days during the fruiting stage. Type IV, a foliar spray consisting of a mixture of CaP and seawater (1ml each) in 725 ml of water at 2% concentration, is sprayed every 14 days during the immature stages of fruiting.

Table 3. Type of application and fertilization schedule for fruit vegetables

Fertilizer	**DAP**[†]
FPJ + OHN	-1
Type II	5
Type II	12
	14
Morning Sickness	19
Type III	26
	28
Type II	30
Morning Sickness	40
Type III	47
Morning Sickness	54
Type III	61
Type II	68
Morning Sickness	75
Type III	82
Type II	89
Morning Sickness	96

[†] Days after planting.

Source : DOA 2002 (unpublished)

An organic village project of 15 ha was established in 2003 involving 16 villagers in Kg. Laklok, Kelantan. Application of IMO technology was started in 2003 and in the first year, sawi (choy sam), cucumber and chilli were grown (Table 4). Increase in yield was obtained for all the crops but yield decrease in 2005 was due to flash floods occurring in the area.

Many farmers who apply this technology have noticed improvement in their trees. For dokong farmers, scabs found on tree trunks disappeared after spraying with IMO2 and FPJ. Fruit setting and the number of fruits were higher compared to trees that were using conventional fertilizers. In fact trees with conventional fertilizers had lower fruit setting and some did not bear fruit at all. In Gua Musang, Gamatain Tradings Company, grows 100 ha of longan (*Dimocarpus longan*) on a hilly, lateritic soil at about 80 m above sea level. At establishment stage, they used compound fertilizer $N:P_2O_5:K_2O$ at 15:15:15. The plants were stunted and the pH of the soil was between 3.2 and 3.5 despite applying lime. Out of the 7,000 seedlings they acquired, about 2,000 died. Upon changing to the Natural Farming technology, with IMO compost applied at the rate of 5 kg per plant, new leaves started to sprout at one month after application. Prior to application, the soil was hard but it has now become more friable and the pH is between 5.5 and 6.5. At present they produce about 140 tonnes of IMO4 for their own use and are now producing an extra 50 tonnes to be sold to other farmers at US$2.72/5 kg.

Table 4. Average yield of crops using natural farming technology in Kg. Laklok

Type of crops	**2003**			**2004**			**2005**			**2006 (April)**		
	Size (ha)	**Total yield (kg)**	**Av. yield**	**Size (ha)**	**Total yield (kg)**	**Av. yield**	**Size (ha)**	**Total yield (kg)**	**Av. yield**	**Size (ha)**	**Total yield (kg)**	**Av. yield**
Choy sam	0.2	4,000	20,000				0.4	4,000	10,000 *			
Cucumber	1.2	14,544	12,120	0.8	20,000	25,000				0.2	3,940	19,700 *
Chilli	0.4	8,000	20,000									
Muskmelon				1.6	18,000	11,250	1.0	11,000	11,000 *	2.0	30,250	15,125
Pumpkin				0.9	7,200	8,000						
Banana							0.5	1,200	2,500	0.4	1,620	4,050

* slight yield decrease due to flash floods

Source: Zainab (pers. comm) 2006

Some of the factors observed by the Natural Farming practitioners were:

1. Input costs reduced by 30%.
2. Life-span of plants increased compared to conventional planting and the average yield was higher than before.
3. Soil structure changed; the soil became more friable.
4. Plants can withstand one-month drought and the soil has a higher water holding capacity.
5. Fruits are sweeter and crispier.
6. Fruity vegetables such as brinjals, chilli and bitter gourd have shinier and even-coloured skins.

Effective microbes (EM)

Effective microbes are microbes that can produce or utilize available nutrients for plants. Kyusei Natural Farming is a famous case where the organisms were isolated by Dr. Teruo Higa. The technology is somewhat similar to the Korean Natural Farming except that the microbes are specific. The isolated groups of microbes are photosynthetic bacteria, lactic acid bacteria and yeasts. More specific information can be found at www.emro.co.jp

To avoid terminology confusion, EM found by Higa should be called EM Kyusei, to distinguish it from other EM formulations. EM Kyusei was introduced to Malaysia in 1992 but its use was not widespread owing to weak technology transfer at that time. In 2005, there was a resurgence of EM Kyusei, which is now slowly being used by farmers especially in Johor, the southern state of Malaysia. Currently, EM Kyusei is used largely in the animal industry for odour removal and animal feed. The use of EM for increasing crop production is small at the moment as training in its use is still embryonic, unlike in Thailand where its use is widespread.

For quarantine purposes, the Ministry of Agriculture and Agro Industry advocates production of EM using selected local micro-organisms. Several EM technologies have been produced in Malaysia: Organic-Gro makes use of liquid waste from an alcohol factory mixed with paddy husks and locally produced inoculants. Another EM is chicken dung-based and added with inoculum from overseas (the microbial component remains a trade secret).

The latest technology developed by EastWorld Multimedia is being promoted in Pahang. The EM was isolated from the jungle of the tropical forest in Malaysia and consists of actinomycetes, nitrifying bacteria, nitrogen fixers, phosphate solubilizers and yeasts and is mixed with lactobacillus. This company supplies the EM and oversees the making of composts in which the microbes are seeded. The making of compost is somewhat unique as the company provides the materials at the cost of US$326 to ten trainees. The materials consist of oil palm fibre, palm oil mill effluent, soil, concrete culverts and the EM at the rate of 10 kg per 250 of mixture. Five concrete culverts were used and were arranged in a row. The materials were mixed and placed into the culverts. After a week, the compost was overturned and placed into the next culvert. A new mixture was made and placed into the first culvert. After four weeks all four culverts were filled. The fifth culvert was left empty so that the heaps could be overturned side-by-side into the culverts. At the end of eight weeks, the first culvert compost became mature and was dried and packed for sale. This company uses ten trainees who are responsible for the care of 1 tonne of compost, with duties such as watering and weekly overturning. The matured compost, Fresh Bio Organic (FBO), is sold and the profit shared amongst the trainer and the trainees. This way, the company makes 10 tonnes per production season. The compost is selling at about US$1,096/tonne. Each trainee obtains about US$817 in profit.

In addition, this company tested out effectiveness on farmers' plots and the results were astounding. Savings in cost are given in Table 5. Moreover, with an average of 25 g/plant used, many physiological changes were reportedly seen, especially on the vegetables. One week from the start of flowering, lady's fingers were reportedly 20 to 28 cm long, cucumbers 500 g to 1 kg in weight and long beans 80 to 90 cm long. Approximately four to five cobs formed on maize plants — an average of two is found on a conventionally grown plant. All of these results were claimed to be better than conventional produce and the rate of application was only 25 g of FBO organic fertilizer per plant. However, the results were not proven scientifically, but merely observations with pictorial representation from farmers who had tried the fertilizer. The nutrient content of FBO is given in Table 6.

Table 5. Savings (US dollars) using EM fertilizer compared to conventional fertilizer

Fertilizer application	**Maize**	**Chilli**	**Amaranthus**	**Cucumber**
Amount in kg				
NPK 15:15:15	520	520		250
NPK 12:12:17:12		250	40	250
Urea	60			
Total cost of fertilizer	114	296	152	193
Amount of FBO (kg)	28	56	40	28
Cost savings between FBO and chemical fertilizers	65	213	76	53

Source: Shamsul 2006 (pers. comm.)

Table 6. Nutrient contents of fresh bio-organic fertilizer

Nutrient content	**N**	**P_2O_5**	**K_2O**	**MgO**	**CaO**	**SO_4**	**pH**	**Moisture**
Amount	2 %	3.9 %	1.4 %	1.0 %	9.0 %	0.5 %	7.0	73. 5%

Source: Shamsul 2006 (pers. comm.)

AMF and its role as a soil enhancer

Arbuscular Mycorrhizal Fungi (AMF) is symbiotic association between plant and soil fungi that plays an essential role in plant growth, plant protection and soil quality. These fungi are efficient in their function as they form gossamer-like formation in the root zone, very much smaller than the plant root hairs. If these thread-like bodies are unraveled, they can be of several miles in length creating more surface area than the plant root hairs. It is this mechanism that allows higher absorption of soil nutrients. The fungal hyphae enter the roots of the plants, thus allowing exchange of soil nutrients to the plant cells. Mycorrhiza also release a mixture of powerful chemicals that release tightly bound chemicals such as phosphorus (P), zinc (Zn) and copper (Cu) and transform them into a form that can be easily absorbed by plants. A host of other AMF advantages is shown in Table 7. AMF is ubiquitous in soils but the number has decreased due to tillage, fertilization, removal of topsoil, erosion, fumigation and over-fertilization. As such, mycorrhiza needs to be reintroduced into soils to sustain growth.

Table 7. Advantages of AMF in agricultural systems

Field	Advantages	Benefits
Agriculture	Agro-system stability	Improved plant roots, soil microflora and the abiotic geochemical soil matrix
	Enhanced nutrient uptake	Improves the absorption of phosphate along with other macro- and micronutrients in addition to better Cation Exchange Capacity (CEC) in the root rhizosphere
	Plant production	Increased shoot and root biomass
	Stress resistance	Drought, cold and pollution
	Resistance to pathogens	Crop protection, reduced use of pesticides, fungicides, improvement in animal, plant, human health and product quality
	Value added to product	Increased synthesis of primary and secondary metabolites
Plant physiology	Improvement in nutrition	Reduced chemical fertilizers (10-30%)
	Carbohydrate level	Improved photosynthetic activity
	Tolerance to water stress	Cultivation of arid soils or soils unfit for agriculture and altered hormonal balance
	Resistance to low temperatures	Diversity of crops in inhospitable areas
Plant morphology	Transformation of root system and root architecture	Adaptation to stress, increased resistance to erosion, fixation of soils, increased numerous and branched roots, root apices and improved production with certain root crops
Plant community	Micro-organism diversity in the subsoil	Re-establishment of soil microflora and improvement of soil quality
	Habitat restoration	Stabilizes biogeochemical cycling
	Survival of partners	Improvement in yields, better acclimatization at transplanting and diversity of plant cover
Micro-propagation plants	High value plants	Uniform size, better growth, shortened nursery period

Source: Rajah & Tang (2005)

The application of mycorrhiza in Malaysia

Use of AMF is not popular in Malaysia because of the difficulty in producing the inoculum and the inoculum spore density. A privately owned company, Malaysian Agri Hi-Tech (MAH), has researched and upgraded the isolation of locally acclimatized species, their propagation and has increased spore quality and quantity. Through research, it has produced various AMF products and has tested them in the field, especially in the oil palm sector.

One of its products, MYCOgold™ has been widely tested in nurseries and existing stands of a number of oil palm estates. MYCOgold contains selected spores of *Glomus*, *Gigaspora*, *Acaulospora* and *Scutellospora* which have been isolated from native Malaysian soils. This product is sold in the market at US$1,089/tonne, has a spore count of 200 to 250 units pe/10 g and has a shelf life of 1 to 1½ years. Tests have shown that enhanced growth of oil palm seedlings was obtained during the nursery phase and the seedlings with MYCOgold reached the stage suitable for transplanting four months earlier than the conventional method (Figure 4).

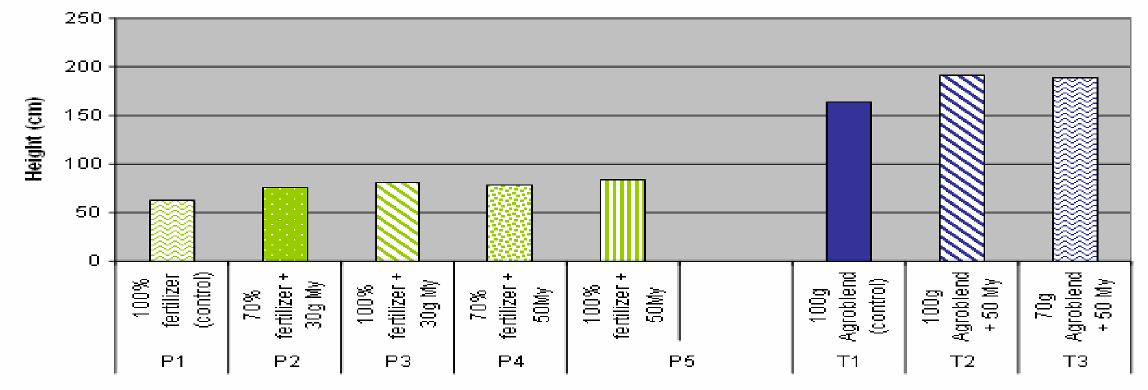


Figure 4. Height of oil palm seedling with different treatments of fertilisers and mycorrhiza

Source: Anon (2001)

However, the usefulness of mycorrhiza has extended its function beyond just growth promotion. The basal stem rot caused by the fungi *Ganoderma* is the most dreaded disease in the oil palm industry. AMF, functioning as a prophylactic against this disease, was noticed in trials conducted by a leading plantation group (Ho 1998). Table 8 shows the degree of rehabilitation success by adding AMF to the affected plants. For protecting trees from *Ganoderma* whilst at the nursery stage, mycorrhiza is incorporated into the soil in nursery bags before seedlings are planted. For existing stands, mycorrhiza is placed in four corners of the plant by digging four pockets 30 to 60 cm deep and 0.5 to 1 m away from the tree. Unlike other fertilizer applications, mycorrhiza must be applied closest to the root zone as soon as possible. Wide-scale use of mycorrhiza, especially at the nursery stage, is expected to control the disease and ultimately decrease the use of pesticides.

Table 8. Yield of moderately and severely *Ganoderma*-infected palms with AMF treatment after 500 days from commencement of trial

	Cumulative yield/palm					
	Moderate			**Severe**		
Category	Control	Treatment	% Control	Control	Treatment	% Control
Original stand	215.54	326.93	(152)	129.70	130.40	(101)
Existing stand	230.94	326.93	(142)	194.55	326.00	(168)

Source: Ho (1998)

Considerations for use of soil-enhancing technologies

1. *Imported inoculum*

   Performance of the inoculum largely depends on the climatic similarity of the country of import. Most of the time the inoculum is not efficient as claimed, as these microbes have to compete with the indigenous microbes in the soil. For instance, microbes selected from temperate countries for use in the tropics may have to compete with the more hardy indigenous microbes in the tropical soils.

2. *Need for quarantine*
   All imported inoculum must be quarantined and tested before being approved for use in Malaysia. The Ministry of Agriculture and Agro Industry follow a very strict protocol on importation of soils, micro- and macro-organisms into the country. The imported material is subjected to tests by four agencies namely the agriculture, animal, fishery and health departments. If any one of these department disagrees with the product content, then the product is not allowed to enter the country. The quarantine is imposed for every single entry of the product. Importers are required to declare all the micro-organisms present in their products. The *E. coli* and *Salmonella* counts should be below safety standards.

3. *Genetically modified organisms (GMO)*
   For soil enhancing purposes, GMOs are totally prohibited.

4. *Colony forming units/g*
   For most products, this information is not available. It needs to indicate the viability of the micro-organisms. The lack of this information explains the inability to produce similar results. It also prompts producers to produce quality products and sustain their market growth.

5. *Shelf life*
   Over time, oxygen, water and nutrients will be depleted in the inocula media. Hence microbial numbers will be reduced. Microbial suppliers should run tests on the survival time and the shelf life should be printed on the outside of the package. Thus farmers will have to use the products as soon as possible to get maximum results. Without the shelf life label, farmers do not know whether the product is still viable and will face losses should the product expire.

6. *Usage procedures*
   More often than not, storage conditions for microbial inoculum are not stated. Most products need dark, moist storage areas — away from direct sunlight. Products in liquid form, such as EM Kyusei, need to be exposed to the atmosphere for a few seconds so as to release gases trapped in the container. Otherwise, the containers will become bloated and, if kept in glass containers, may even break due to the gas build-up.

7. *Scientific back-up*
   Some of the technologies that are produced locally lack scientific results to back up the claims. Testing on farmers' fields is not enough as there are many variations in the field. Research needs to be conducted to verify efficiency and dosage of the products before they are marketed. The products are analyzed for their contents particularly nitrogen, phosphorus, potassium, calcium and sulphur contents. The pH, conductivity and carbon content are essential also. Products are then exposed to several trials to determine the rate of application on various crops and soil types.

8. *Transfer of technology*
   Intensive training and demonstration is needed to train farmers in the use of microbial inoculants. Microbial inoculants need specific conditions for use unlike conventional

fertilizers. For instance, IMO and EM require a few days of fermentation with molasses before they can be used efficiently. Ill-prepared preparations will result in lower crop productivity and thus discourage farmers from further use as in the case of EM Kyusei, which did not take off in 1992. In composting, many farmers simply leave their compost heap without consistently overturning it, which results in poor quality compost. The importance of keeping the Bokashi pile within 40 to 45^{o} C must be stressed in order to obtain good fermentation, devoid of undesirable odours. Application of materials must be taught as some materials need to be incorporated into the soil, some applied at the circumference of the root zones and in the case of AMF, applied very near to the root zones.

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