ORGANIC RICE FARMING SYSTEM

(Studies on the effect of organic matter on rice yield, soil properties and environment)

Research Project Report of Perez-Guerrero Trust Fund (PGTF) for Economic and Technical Cooperation among Developing Countries, Members of the Group of 77

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J. Samy, A. Xaviar and A. B. Rahman

Strategic, Environment and Natural Resources Research Center,
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SUMMARY

Rice production is heavily dependent on the use of chemical fertilizers and pesticides to produce high yields. This is detrimental to the rice agro-ecosystem, and the recent stagnation or even decline in rice yield in some areas may be partly attributed to the prolonged use of inorganic fertilizers and chemicals. The research on organic farming in rice is directed towards a complete or partial substitution of chemical fertilizers with organic fertilizers to enhance rice yield. The related problem of environmental degradation with the application of organic matter in flooded rice soil due to increased emission of methane is also studied. The main areas of research are: 1. Assessment of impact of past inorganic fertilizer applications and a study of current nutrient requirements to enhance rice yield, 2. Effect of various forms of organic fertilizers on major soil properties and yield of rice, and 3. Emission of greenhouse gas methane due to the use of organic matter in rice soil.

The studies show that continual usage of N, P and K fertilizers in rice over the past 25 years have caused nutrient imbalances non-conducive to high yields. The imbalance has been in the nutrient ratios leading to excesses or deficiencies of major and minor elements and organic matter status of soil. This has caused a general stagnation or a decline in rice yields in some areas. An Expert System of Nutrient Management (ESNM) for rice taking into consideration the various soil and environmental parameters was developed, and it showed that rice yields can be enhanced by 15-26% by correction of these specific nutrient imbalances. In Besut the increase in yield ranged from 30 to 62%. A complete computer programme on the Expert System has been prepared to directly

derive precise fertilizer recommendations for any rice area of the country, and this has been submitted to MARDI.

The incorporation of organic matter in rice soils can improve rice yields and the highest enhancement was obtained with a combination of both organic and inorganic fertilizers. The potential organic matter sources suitable for rice are POME, rice straw and effective microorganisms. Organic matter like POME may be able to replace inorganic fertilizers provided they are applied regularly at about 20 t/ha, which is a large amount to handle. Straw also has potential as an organic fertilizer but it requires special management techniques to allow it to decompose within three weeks. It has to be well spread out in the field in contact with soil and the field should not be completely submerged. Effective microorganisms sprayed on the straw can further hasten the decomposition of straw. Effective microorganisms was shown to marginally enhance the yield of rice by 10-20%. *Sesbania rostrata* is not effective and gives the lowest yield, but in combination with other organic matter like POME or effective microorganisms the yield can be enhanced to be close to that of NPK.

The oxidation-reduction potential of soil with the incorporation of organic matter fluctuates with growth of rice crop and is the lowest at about the maximum tillering stage with a minimum of -230mV. There were only slight differences in pH of 0.5 units throughout the growth of the rice crop. There was a general increase in ferrous iron content with the use of organic matter but no visual symptoms of iron toxicity was observed.

It was evident that organic matter sources like sesbania, POME and effective microorganisms delayed the release of exchangeable ammonium nitrogen. This phenomenon is beneficial as it is at later growth stages of rice that the soil becomes most limiting in nitrogen to provide the crop needs for grain formation.

The use of organic matter in flooded rice soil has environmental problems as it enhances the emission of the greenhouse gas methane. It was found that use of effective microorganisms can substantially reduce the emission of methane in specific organic matter sources.

The studies show there is good potential for organic based rice farming with a combination of organic and inorganic fertilizers to attain maximum yields. It is possible to plant rice by organic farming by maintaining high organic matter status and obtain high yields as shown in the use of POME or a combination of various organic matter sources. However, the amount of organic matter required regularly is very high. Effective microorganisms play an important positive role in the management of organic matter in rice field and to minimize the emission of methane.

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1. INTRODUCTION

Rice is one of the most important food crops in the world, and it is the staple diet of 1.6 billion people in Asia. Average yield of rice in Malaysia is 3.2 t/ha which is low compared to an average yield of 5.4 t/ha from East Asian countries. Large sums of money have been invested in providing irrigation and drainage infrastructure facilities to enable double cropping of rice using high yielding varieties with the latest agronomic practices in attempts to attain high rice yields. It is however of prime concern that over the past two decades there has been a steady increase in the level of fertilizers, pesticides and weedicides used in rice cultivation to maintain yields against the mounting pressures of insect pests, diseases and weeds. The implementation of the integrated pest management system has helped to provide some check on the application of chemicals but invariably with the occurrences of periodic pests outbreaks large amounts of chemicals are still being widely used to save the crop. There is an alarming concern of a future demand for still higher levels of chemicals to be used in order to maintain crop yields.

It is believed that the introduction of modern technologies have grossly altered the original rice ecosystem which maintained a stable level of soil fertility, a low level of weed species, a population of predator insects to ward off harmful insects and a built-in natural resistance of rice varieties to diseases. The present rice ecosystem tilts at an unknown level of unstable equilibrium largely maintained by the use of chemicals. The sporadic devastating yield losses caused by large pests populations are examples of the extent to which the natural rice agro-ecosystem has been stretched. Apart from this, the excessive dependence on chemicals pose health hazards and are harmful to the environment. It is timely that positive steps are taken to study the natural rice agro-ecosystem and methods to sustain yield levels with the minimal use of chemicals.

There is much concern that recent rice yields in Asia has been stagnating or even declining in some areas. Malaysia is no exception, and it is widely believed that the prolonged use of inorganic fertilizers and other chemicals could be one of the causes. Scientists now have a replacement for the green revolution and call it genetic revolution. They claim that by genetic manipulation it is possible to obtain 10 to 17t/ha of rice and wheat. This is doubtful because soils, by losing organic matter and biological activity, are becoming the most limiting factor of plant production (Bourguignon and Gabucci, 1996).

The scope of research on organic rice farming system is indeed very wide, and the studies undertaken here are confined to current crop nutrient requirement effect of organic fertilizers, and environmental aspects. The main areas of research are:

1. Assessment of impact of past inorganic fertilizer applications and a study of current nutrient requirements to enhance rice yield.
2. Effect of various forms of organic fertilizers on major soil properties and yield of rice.
3. Emission of greenhouse gases due to the use of organic matter in rice soils.

The research project on organic rice farming system was initiated in 1992 and financed by the Perez-Guerrero Trust Fund (PGTF) for Economic and Technical Cooperation among Developing Countries, Members of the Group of 77. The studies were located in the major irrigation schemes in the country: Muda Agricultural Development Authority (MADA), Kemubu Agricultural Development Authority (KADA) and Project Barat Laut Selangor (PBLS) as shown in Figure 1.

The research on organic farming in rice is directed towards a complete or partial substitution of chemical fertilizers with organic fertilizers to enhance rice yield. The related problem of environmental degradation with application of organic matter in flooded rice soil due to increased emission of methane is also studied.

2. ORGANIC FARMING

There is presently widespread interest on various types of alternate agricultural systems such as organic farming, natural farming, biological farming, ecological farming, low external input sustainable agriculture (LEISA) etc. Organic farming is defined as: "a production system which avoids or largely excludes the use of synthetically compounded fertilizers, pesticides, growth regulators and livestock feed additives. To the maximum extent feasible, organic farming systems rely upon crop rotations, crop residues, animal manures, legumes, green manures, off-farm organic wastes, mechanical cultivation, mineral-bearing rocks, and aspects of biological pest control to maintain soil productivity and tilth, to supply plant nutrients, and to control insects, weeds, and other pests" (USDA, 1980). It is clear from this definition that organic farming is not necessarily ancient

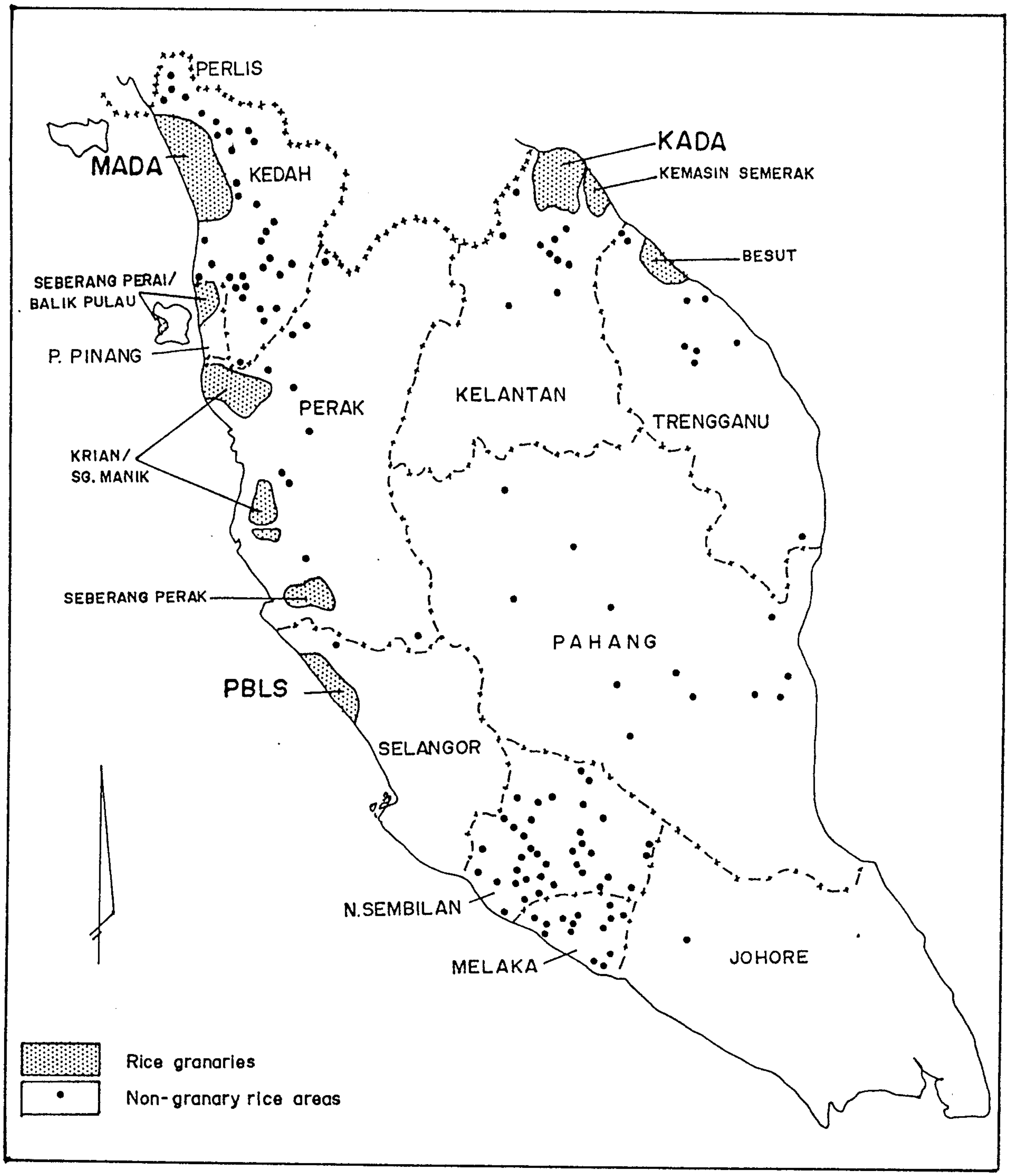

Figure 1. Location of organic farming trial site - MADA, KADA and PBLS

farming or traditional farming. It is rather a practice that uses traditional knowledge and adapts it to modern farming systems, for the adequate recycling of nutrients and to maintain soil quality. The definition also allows much leeway in the practice of organic farming as it uses words like 'avoids or largely excludes' and also 'to the maximum extent feasible'. It is not rigid in imposing conditions on the organic farming system and can probably be better referred to as 'organic based farming'. Organic based farming attempts as far as possible to use organic fertilizers and reduce the use of chemical fertilizers in order to sustain soil fertility and maintain high yields. It is reported that the most efficient crop production system consists of the use of both organic and chemical fertilizers (ASPAC, 1991).

It is necessary to distinguish between the USDA definition of organic farming and the true or 100% organic farming. Generally the term 'organic farming' would refer to 100% organic farming and some of the basic concepts are as follows:

1. The farm is a self-contained sustainable ecosystem that blends with the larger natural ecology of the region.
2. The maintenance of soil fertility, essentially the organic matter, is the central criterion in the sustainability of the farming system.
3. A mixed farm is a basic principle with crop diversity and integration with livestock or poultry where possible.
4. Pests should be below the economic threshold level. Any outbreak of pests is regarded as an indicator of shortcomings in the farming system.

The three main operations in the practice of organic farming are as follows:

1. Conservation

   There is a need to conserve all farm resources. In particular soil and water conservation measures are very important to prevent erosion and loss of soil, water and nutrients.

2. Recycling

   Recycling of crop residues and animal wastes is necessary for soil fertility management. This would also include the use of legumes as green manure in suitable rotation with crops.

3. Integrated Systems

   In the integrated systems, it is attempted to promote internal biological cycles and improve agronomic production techniques. Crop diversity is maintained in order to attain balances of predator insects with pests. Integration of crops with livestock and poultry or fish rearing where possible would complement the system towards a holistic management of the farm.

The beneficial role of organic matter can be summarized as follows:

(i) Maintenance of structure

(ii) Improvement of soil physical properties

(iii) Decreased susceptibility to erosion

(iv) Encouragement of microbial activity

(v) Increase in available plant nutrients

There is currently an increasing concern on the heavy use of chemical fertilizers to the exclusion of organic fertilizer which may have possible long term effects in soil structure, crop productivity and off-farm pollution. Therefore green manures and other organic fertilizers have a number of apparent agronomic and environmental advantages over chemical fertilizers. Sesbania and azolla are among the most widely evaluated biofertilizers for rice. Sesbania is reported to be widely used in South China. It contains high amounts of N, P, K, S and microelements (Kundu and De Datta, 1988). Azolla did not receive acceptance because of its requirement for phosphorus fertilizers and pests and disease problems. Rice straw is another organic amendment which is easily available in plentiful supply within the rice growing environment. A long term incorporation of straw can increase content of organic carbon, nitrogen available phosphorus, potassium and silica (Ponnamperuma, 1984).

The use of organic materials in rice is not without problems. The recent awareness of environmental issues such as the 'greenhouse effect' has a direct effect on the potential use of organic materials in flooded soils. The decomposition of organic materials releases carbon dioxide and methane, both of which are considered to be greenhouse gases.

2.1 Organic Products

There are various types of organic products in the market and they are all generally termed as organic fertilizers. A broad classification of the products would be as follows:

1. Poultry and animal dung

2. Agricultural by-products

These are composted plant residues and agro-industrial wastes, e.g. bio-organo, biopost, amina, palm oil mill effluents (POME) etc.

3. Microorganism preparations

These consist of some 40 to 80 different types of microorganisms in combination, e.g. Bioferti, Effective Microorganisms (EM) etc.

4. Humic acids

These are extracts of specific parts of humic acid molecule chain, e.g. Vigrifol

5. Sea weed extracts

These are compositions of amino acids together with organic and mixed plant nutrients, e.g. Megafol, Kozgro

6. Organic based fertilizers

Consists of NPK fertilizers bound in humus material, e.g. complehumus, kokei etc.

7. Spiked organic products

NPK added to organic materials, e.g. Bio-organic + NPK, Kozgro-P, POME + NPK, etc.

8. Green manure

Legume plants grown and ploughed into the soil, e.g. *Sesbania rostrata*

3. DESCRIPTION OF ORGANIC FARMING TRIAL SITES

The most suitable rice growing areas of Malaysia have been identified and developed as major rice granaries of the country with the provision of modern drainage and irrigation infrastructures for double cropping of rice. There are eight major rice granaries with a total area of 212,497 hectares and produce some 60% of the total national production of rice. The three sites selected for the organic farming trials, MADA, KADA, and PBLS are among the biggest rice granaries of the country (Figure 1). The MADA granary, produces 58% of national rice production, KADA produces 11%, and PBLS about 11% and the remaining 5 smaller granaries produce about 20%.

3.1 Climate

The climate of Malaysia is a typically hot and humid tropical. Total rainfall is high, exceeding 1600 mm a year and well over 2500 mm in many areas. The mean annual rainfall is over 2000 mm, and the mean daily temperature is above 22°C. MADA in the northwestern part of Peninsular Malaysia has a tropical monsoon climate with a distinct dry season when the monthly rainfall is less than 50 mm. KADA in the east coast of Peninsular Malaysia comes under the strong influence of the northeast monsoon. Total annual rainfall here is in the range of 2200 to 3000 mm with 70% of rain falling in the months of November to January causing serious floods. The third organic farming trial site, PBLS lies along the middle of the west coastal plain of Peninsular Malaysia has a lower rainfall of about 2000 mm, which is more evenly distributed, with a short dry period in January and August.

3.2 Soil

The major physico-chemical properties of rice soils of MADA, KADA and PBLS are given in Table 1.

The MADA and PBLS rice granaries are located on the west coast of Peninsular Malaysia which is shielded from the direct rain bearing winds of the northeast monsoon by the mountains of the main-range on the east, and from the southwest monsoon by the island of Sumatra on the west. Thus these areas on the west coast enjoy a relatively calm sea. The gentle hill slopes with slow meandering rivers deposit clayey sediments on the coastal plain. The deposits range from low river terraces (inland) to brackish water, estuarine and marine sediments (near the coast). A typical feature of the rice soil of MADA is the zoning of the marine and riverine soil sediments, more or less parallel to the coast. In PBLS the inland rice soils overlay the beginning of deep peat swamp.

KADA in the east coast of Peninsular Malaysia is exposed to the full intensive of the northeast monsoon from the open South China Sea. There is serious flooding, soil leaching, and erosion. The rivers are swift, and there are deposits of sandy beach ridges. The rice soils are typically riverine and are developed on terraces associated with the major rivers. The main rice area is KADA in Kelantan river plain where the elevation ranges from 14 meters above sea level at the river beach to about 0.3 meters above sea level in the depression areas. The toposequence of the soil across KADA illustrates that the morphology of the soil is determined by topographic position, soil permeability and ground water fluctuation pattern.

Table 1. Soil characteristics of MADA, KADA and PBLS

Soil characteristics	MADA	KADA	PBLS
Sand (%)	6.1 ±1.1	27.6 ±4.1	6.1 ±1.8
Silt (%)	36.7 ±1.5	25.1 ±1.4	39.5 ±1.2
Clay (%)	57.4 ±1.7	47.3 ±3.4	54.4 ±2.1
pH	4.40 ±0.10	4.81 ±0.07	4.4 ±0.15
Conductivity (uS/cm)	45 ±10	343 ±220	162 +43
Available P (ppm) (Bray & Kurtz No 2)	21.2 ±3.7	8.9 ±1.2	6.8 ±1.6
Organic carbon (%) (Walkley & Black)	3.0 ±0.1	2.0 ±0.4	5.7 ±1.1
Nitrogen (%)	0.23 ±0.02	0.14 ±0.06	0.06 ±0.01
CEC (meq/100g)	21.6 ±0.8	6.9 ±0.7	15.0 ±1.9
Exch. K (meq/100g)	0.33 ±0.03	0.84 ±0.43	0.32 ±0.05
Exch. Na (meq/100g)	0.41 ±0.04	0.17 ±0.02	0.76 ±0.10
Exch. Ca (meq/100g)	3.48 ±0.23	1.52 ±0.19	2.55 ±0.60
Exch. Mg (meq/100g)	1.54 ±0.12	0.67 ±0.07	2.99 ±0.65
Exch. Al (meq/100g)	4.13 ±0.44	1.24 ±0.11	3.90 ±0.67

4. INORGANIC FERTILIZER PRACTICES

Application of inorganic fertilizer to rice commenced in the 1970's with the advent of double cropping using high yielding rice varieties. Prior to this very little inorganic fertilizers were used for the traditional indica varieties, and farmers depended mostly on bat guano organic fertilizer. Since 1970, various levels of subsidy fertilizer were given to farmers, and in 1979, the government introduced a full fertilizer subsidy of free fertilizers at the rate of 80 kg N/ha, 30 or 40 kg P_2O_5/ha (depending on the area) and 30 kg K_2O/ha. In the late 1980's there was a gradual shift from transplanted rice to direct seeding due to the acute labour shortage as farm labour transferred to the industrial sector. The nutrient management system in the granaries has therefore changed to suit direct seeding rice culture. The fertilizer rate recommended for direct seeding is 100 kg N/ha, 30 kg P_2O_5/ha and 20 kg K_2O/ha. The application of N is split as ¼,¼ and ½ at 25 days, 45 days and 70 days after seeding respectively. The P_2O_5 and K_2O are applied with the first application of N. Although the recommended fertilizer rate has increased, the free subsidy fertilizer remains the same. The farmers therefore purchase themselves the additional fertilizers. They generally use additional compound fertilizers e.g. Nitrophoska blue (12 : 12 : 17 : 2), nitrophoska green (15 : 15 : 15), other compound fertilizers (8 : 8 : 8 : 3; 16 : 14 : 7) or urea. The rates range from 40 to 50 kg/ha of fertilizer products, and the time of applications vary from 30 to 75 days after seeding.

The rice yield trend over the past 20 cropping seasons for the three granaries MADA, KADA and PBLS are shown in Figure 2. The mean yield for the granaries has never exceed 5 t / ha despite fertilizer subsidy (since 1979) of 80 kg N / ha, 30 or 40 kg P_2O_5 / ha and 30 kg

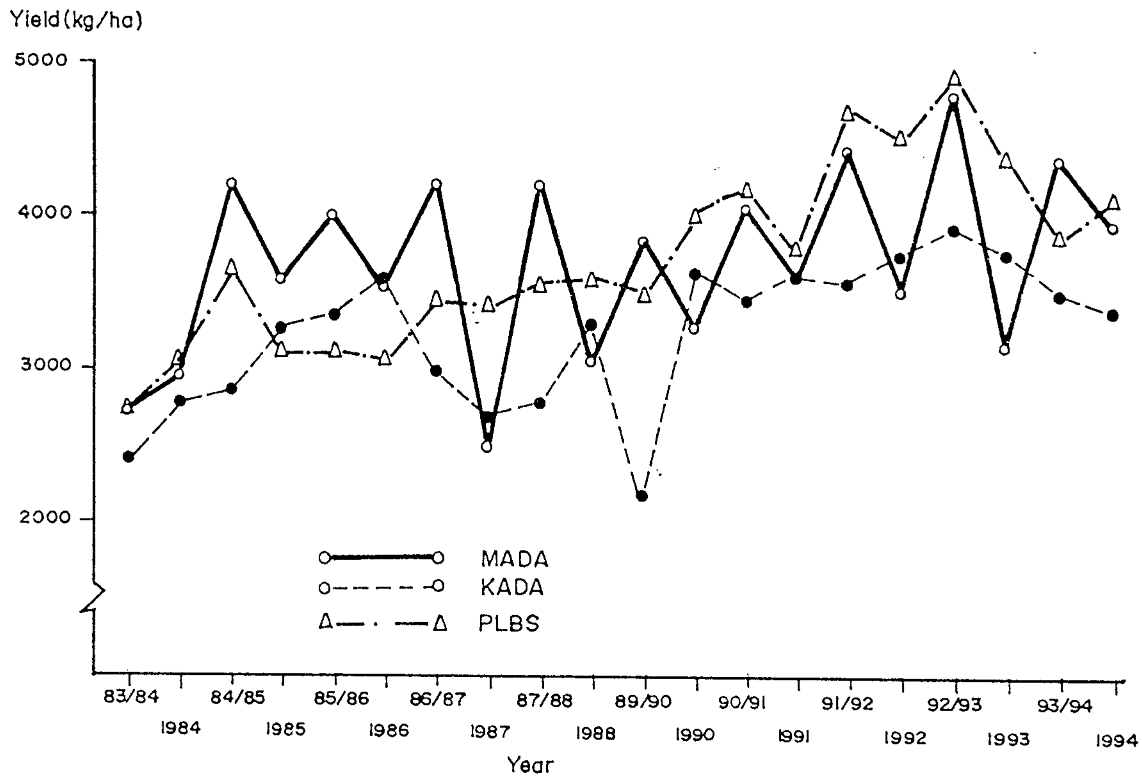

Figure 2. Rice yield trend in MADA, KADA and PBLS from 1983 to 1994 (20 cropping seasons)

K_2O/ha. In recent years the mean yield has been 3.2 to 4.2 t/ha. Response of rice to added nutrients has generally been economic only for nitrogen. Fertilizer recommendations have included phosphorus and potassium more on the basis of providing balanced nutrition, and as a precaution to ensure such nutrient elements are not yield limiting.

Multilocational trials using various levels of N, P, and K were conducted in MADA, KADA and PBLS granary areas during 1980-1986. Generally, the response pattern is similar except for the difference in elevation of the response curves (Figure 3). The response curves for PBLS occur at distinctly higher elevation than others. At all sites there was significant response to nitrogen for rates up to 80 kg N/ha and yield increased (though not significant) up to 120 kg N/ha (Table 2). Phosphorus response was obtained only in MADA and KADA, and only for rates up to 30 kg P_2O_5/ha. Response to potassium was obtained only in KADA.

Table 2. Rice yield response to nitrogen in MADA, KADA and PBLS

Granary region	Yield (t/ha)			
	0 kg N/ha	40 kg N/ha	80 kg N/ha	120 kg N/ha
MADA	3.39±0.18	4.10±0.20	4.33±0.20	4.51±0.20
KADA	3.26±0.19	3.85±0.17	4.03±0.19	4.25±0.19
PBLS	3.96±0.23	4.62±0.30	4.88±0.30	5.08±0.38

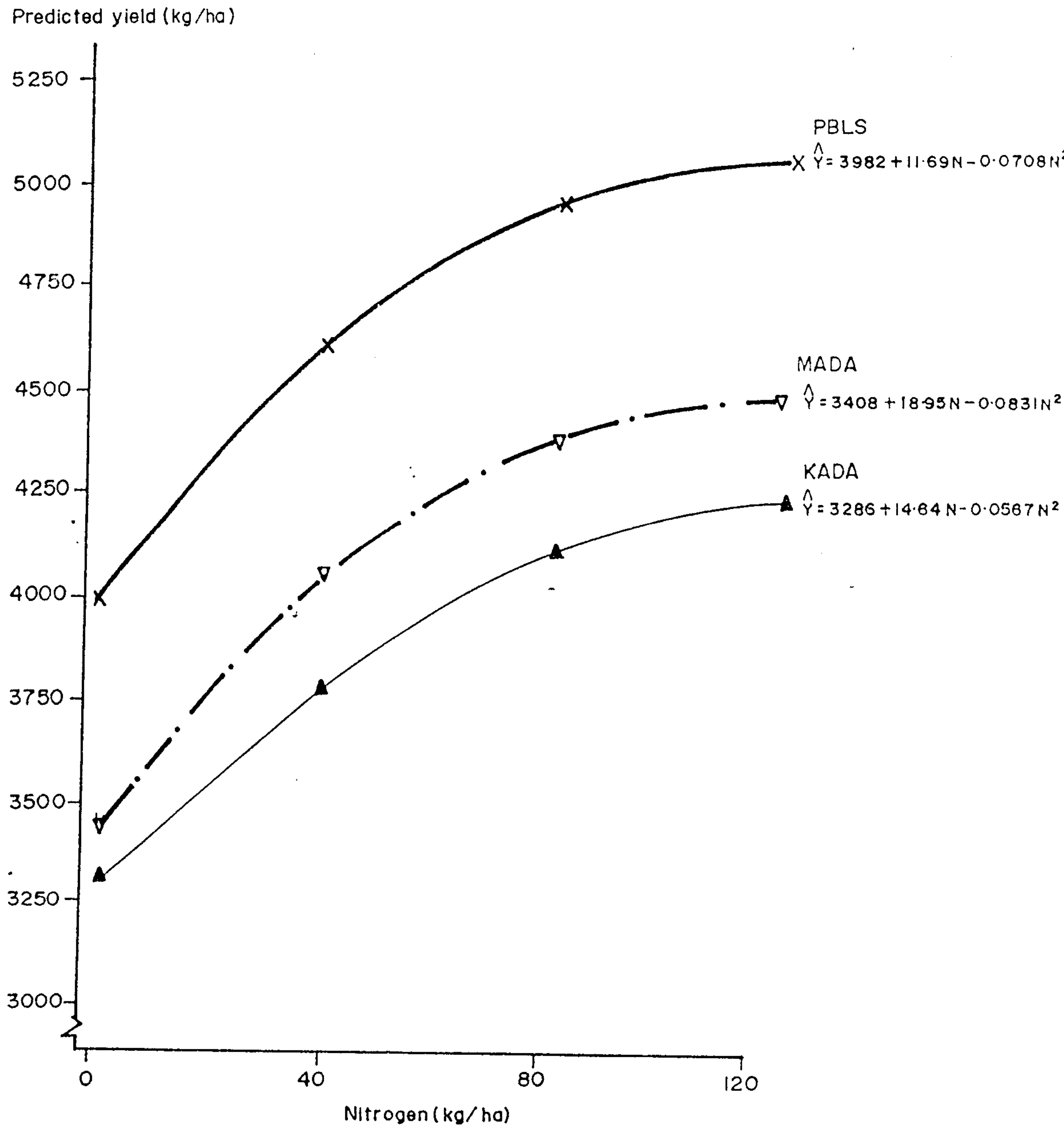

Figure 3. Response to nitrogen fertilizer application in MADA, KADA and PBLS (1980-1986)

4.1 Base Yield

Base yield is the yield obtained with no fertilizer and is a good indicator of soil productivity without amendments. It depends on the native nutrients in the soil, current management, and the residual effects of previous management. For the granary region of MADA and KADA base yields are lower than 3.5 t/ha, while at PBLS they attain 4.0 t/ha (first column Table 2). The magnitude of base yield indicate the amount of native nitrogen that can support rice yields. This accounts for 75% of yield in MADA, 76% in KADA and 77% in PBLS. Therefore the average yield contribution due to fertilizers is only about 24%.

The soils that generate these base yields in the granary regions have the characteristics summarized in Table 1. Neither total soil nitrogen, nor the related organic carbon content, show strong correlation with base yield of rice (Table 3). However, textural properties, CEC, exchangeable Ca, exchangeable K, and conductivity do correlate with base yield. Sand content shows the strongest (negative) correlation - indicating low yields at high sand content and conversely indicating a positive and significant correlation with clay content. Correspondingly, CEC and exchangeable Ca have high positive correlation with base yield. Exchangeable K has a significant negative correlation, indicating perhaps excessive K content due to continuous application of potash fertilizers. It is reported that sufficient K is provided by irrigation water, and application of potash fertilizers is consequently unnecessary (Kanapathy, 1968).

Table 3. Correlation of base yield of rice with soil characteristics

Soil characteristic	Correlation coefficient
Sand	-0.45**
Silt	0.39
Clay	0.34**
pH	-0.14ns
Conductivity	-0.35**
Available P	0.15ns
Organic carbon	-0.00ns
Nitrogen	-0.11ns
CEC	0.40**
Exch. K	-0.31**
Exch. Na	0.04ns
Exch. Ca	0.40**
Exch. Mg	0.14ns

**: Significant at the 0.01% level;
ns: not significant at the 5% level.

5. CURRENT NUTRIENT REQUIREMENT OF RICE

As part of the organic farming studies the current nutrient status assessment of rice crop was carried out. To identify the nutrient requirement of rice, a crop nutrient survey was initiated in 1992 in farmers' fields in MADA and KADA. Crop-cut tests were made for yield, and plant samples collected for tissue analysis of nutrient contents. The Diagnosis and Recommendation Integrated System (DRIS) was used to identify nutrients limiting yield; and mean tissue nutrient contents were compared with nutrient contents known to be critical for rice. DRIS also compares absolute nutrient levels, and nutrient ratios between high yielding and low yielding populations. Norms developed from the high-yielding group of farms were used to develop composite indices to indicate which nutrient or nutrient-ratio need to be adjusted to increase yield on the low-yielding farms. The norms can be used to identify the probable cause of the disorder, whether an excess or a deficiency of a particular nutrient causes an imbalanced nutrient ratio. The mean rice tissue nutrient contents in MADA and KADA are given in Table 4. The study identified deficiency of nitrogen, calcium, copper and boron in MADA (Samy, *et. al.*, 1992); and nitrogen, copper, boron and sulphur for KADA. Subsequently, to facilitate a more precise and holistic identification of nutrient requirement, an Expert System of Nutrient Management (ESNM) was developed, which essentially integrates plant nutrient critical levels, soil nutrient critical levels, plant nutrient ratios, and soil-related modifying factors which also influence rice growth (Xaviar, *et al.*, 1996). It was found from field validation trials, that following the recommendation of the Expert System there would be a 15 to 26% yield increment, with mean yields in MADA surpassing 5 t/ha. In Besut the increase in yield ranged from 30 to 62%. A complete computer programme on the Expert System has been prepared to directly derive precise fertilizer recommendations for any rice area of the country, and this has been submitted to MARDI.

It is clear that the continual usage of only N, P and K fertilizers in the past recommendations have caused nutrient imbalances non-conducive to high yields. The correction of these imbalances and incorporation of organic matter can be the solution to the recent stagnation or decline in rice yields.

Table 4. Nutrient content of rice tissues at harvest in MADA and KADA during 1992-1995

Nutrients	MADA	KADA
N %	0.56 $\pm$ 0.01	0.57 $\pm$ 0.01
P %	0.08 $\pm$ 0.00	0.10 $\pm$ 0.00
K %	1.75 $\pm$ 0.01	1.86 $\pm$ 0.04
Ca %	0.28 $\pm$ 0.00	0.35 $\pm$ 0.01
Mg %	0.16 $\pm$ 0.00	0.11 $\pm$ 0.00
Mn ppm	271.96 $\pm$ 6.26	732.58 $\pm$ 43.61
Fe ppm	273.78 $\pm$ 7.27	483.62 $\pm$ 25.48
Cu ppm	1.86 $\pm$ 0.04	1.42 $\pm$ 0.10
Zn ppm	43.00 $\pm$ 0.41	82.15 $\pm$ 1.78
B ppm	6.85 $\pm$ 0.07	5.03 $\pm$ 0.18
S %	0.13 $\pm$ 0.00	0.10 $\pm$ 0.00

6. ORGANIC FERTILIZER TRIALS

The organic materials studied were *Sesbania rostrata* (green manure); Palm Oil Mill Effluent (POME); bioferti (commercially available microbial organic fertilizer);

complehumus (commercially available organic fertilizer); and rice straw. A control plot receiving only nitrogen, phosphorus and potassium was included (Table 5).

Table 5. Organic fertilizer treatments

Number	Treatment
1. NPK	NPK fertilizer at 100:40:30 P and K applied 15 DAS. Nitrogen is applied in three split doses at 15 DAS, 40 DAS and 55 DAS in the ratio of ¼ : ¼ : ½
2. Sesbania	Sesbania sowed at 125 gm/plot. Sesbania plants are ploughed in at 45 days old
3. Sesbania + N	Same as treatment 2. At 55 DAS nitrogen fertilizer applied in similar amount as treatment 1 for that stage
4. Sesbania + POME	Same as in treatment 2. POME applied at the rate of 6000 kg/ha and incorporated into the soil
5. POME + N	POME at 6000 kg/ha, incorporated into the soil and nitrogen fertilizer applied at 55 DAS as in treatment 1 for that stage
6. Complehumus	At 15 DAS, 2.8 kg/plot is applied. Similarly at 40 DAS. At 55 DAS, 5.6 kg/plot is applied
7. Sesbania + Bioferti + N	Same as in treatment 2. Bioferti applied at 1125 gm/plot at day of Sesbania incorporation. Nitrogen applied at 55 DAS as in treatment 1 for that stage
8. Bioferti + NPK	Bioferti applied at time of sowing seeds. NPK as in treatment 1
9. Straw + NPK	Straw incorporated at the rate of 6 t/ha, six days before sowing of seeds. NPK as in treatment 1

The trial was conducted in KADA at two locations, Jerus (Pasir Putih series) in the first season (Dry season 1992) and at Perol (Chempaka series) in the second season (Wet season 1992).The trials were laid out in a randomized block design with four replications. Method of crop establishment was direct seeding. Soil pH and oxidation-reduction potential were determined in all the treatment plots of the first replicate at Perol at weekly intervals commencing from the incorporation of the organic matter.

6.1 Oxidation-Reduction Potential (ORP)

The Sesbania seeds were sown under saturated condition and a water level of 5-10 cm was maintained during the growing period up to 55 days. The Sesbania plants were then slashed with a bushcutter and incorporated into the soil. Samples were taken to determine approximately the amount of biomass incorporated. Treatments with other organic amendments (POME and rice straw) were also incorporated on the same day.

One month from date of sowing, the Sesbania plots were under reduced condition with an ORP of -68mV, pH of 6.11 while fallow plots had an ORP of -101mV and a pH of 6.75. The difference is attributed to microbial activities, probably the effect of N fixing activities in the root nodules of the Sesbania plants which resulted in a lesser reduced state and the root exudations caused a lower level pH. However, on the day of incorporation, with the water drained off from the field the ORP in all the plots was about +220mV. The field was inundated with water soon after the incorporation activities. Within three days of organic matter incorporation, the oxidation-reduction potential dropped to +9mV in all plots. At the 6th day of incorporation (0 DAS), there was a noticeable difference in the redox potential between the treatments but the pH was not markedly different between the treatment plots. Plots with only inorganic fertilizers had an ORP of -140mV (Table 6). Plots receiving organic matter had an ORP in the range of -132 to -165mV with plots of straw incorporation being the most reduced.

Table 6. Oxidation-reduction potential (mV) at the various growth stages

Treatment	0 DAS	30 DAS	56 DAS	74 DAS
NPK	-104	-127	-119	-85
Sesbania	-132	-121	-145	-71
Sesbania + N	-152	-166	-174	-81
Sesbania + POME	-148	-165	-187	-203
POME + N	-158	-212	-189	-185
Complehumus	-126	-219	-221	-139
Sesbania + Bioferti + N	-108	-215	-153	-128
Bioferti + NPK	-119	-196	-164	-97
Straw + NPK	-165	-192	-144	-123

DAS: Days after sowing

The oxidation-reduction potential fluctuates with growth of the rice crop, sometimes increasing and subsequently decreasing and the degree of fluctuation varies between treatments (Figure 4). Several treatments showed a decreasing ORP from the period of

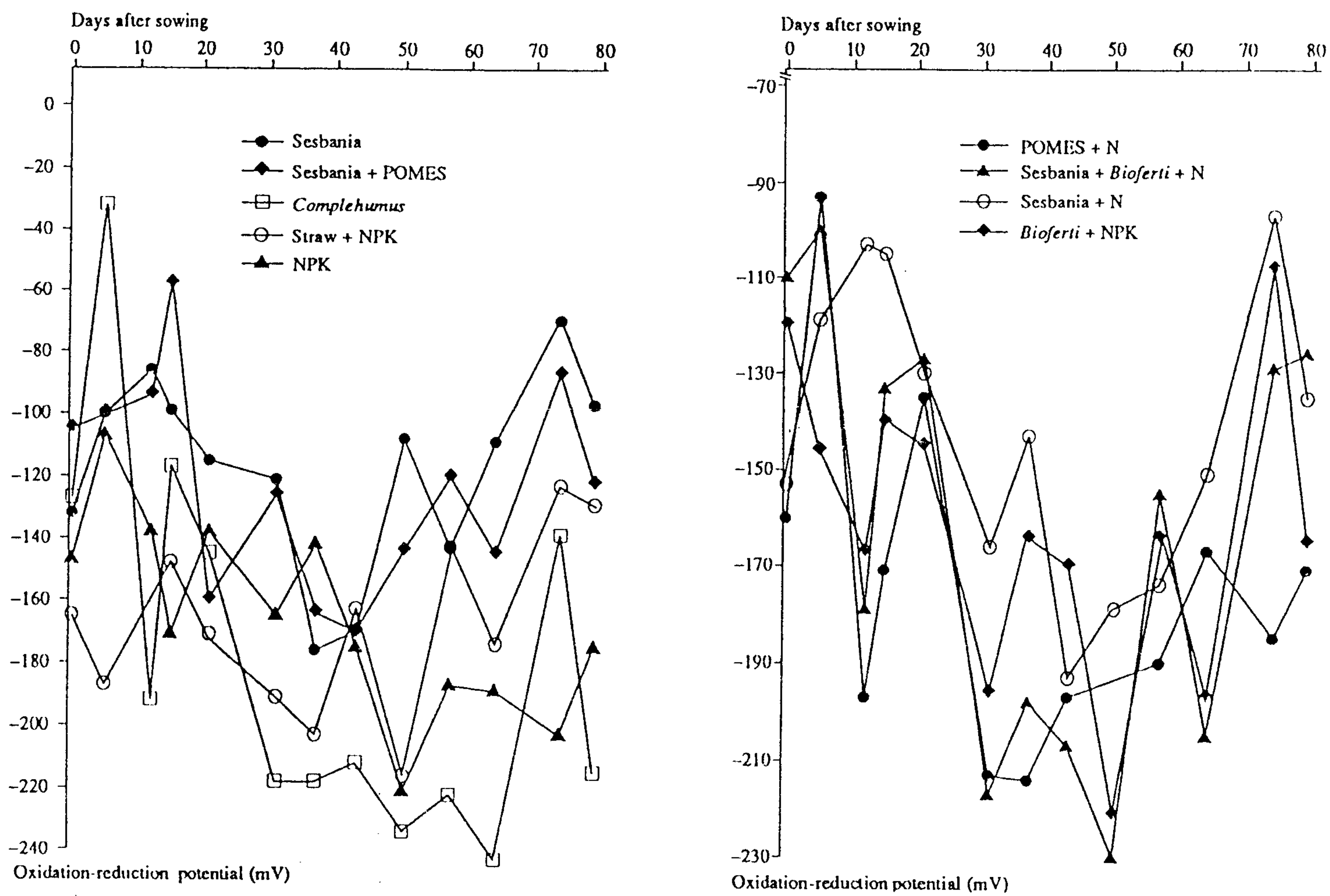

Figure 4. Changes in oxidation-reduction throughout the growing period with organic amendments

rice seed broadcast to 15 days after sowing and then increases progressively until the maximum tillering stage, after which there is a decreasing trend.

Fertilizer applications causes a decline in oxidation-reduction potential. This is probably due to a more reduced environment created by the organic matter decomposition which is enhanced with fertilizer application. This phenomena is exhibited by all except treatment plots Sesbania + N and POME + N, and is more clearly manifested in the complehumus treatment, an organic based fertilizer applied at the three growth stages of 15 DAS, 25 DAS and Panicle Initiation. Treatments Sesbania + N and POME + N received organic matter additions six days prior to seed broadcast and had no inorganic fertilizer additions at the vegetative stages.

6.2 pH

There were only slight differences in pH between treatments and variations in pH within a treatment during the crop growth period were within 0.5 units (Figure 5). pH decreases initially during the first week of seedling establishment for all treatments except in treatment Sesbania + Bioferti + N which had an application of Bioferti comprising of some microorganisms when the Sesbania was incorporated. The decrease in pH following application of organic matter is more sudden for plots with Sesbania and/or Bioferti. Among the treatments evaluated straw incorporation showed the least fluctuation. pH decreased from 6.72 to 6.50 in the first week and generally maintains this value for the remaining crop growth period. It is evident from the figure that it is unlikely

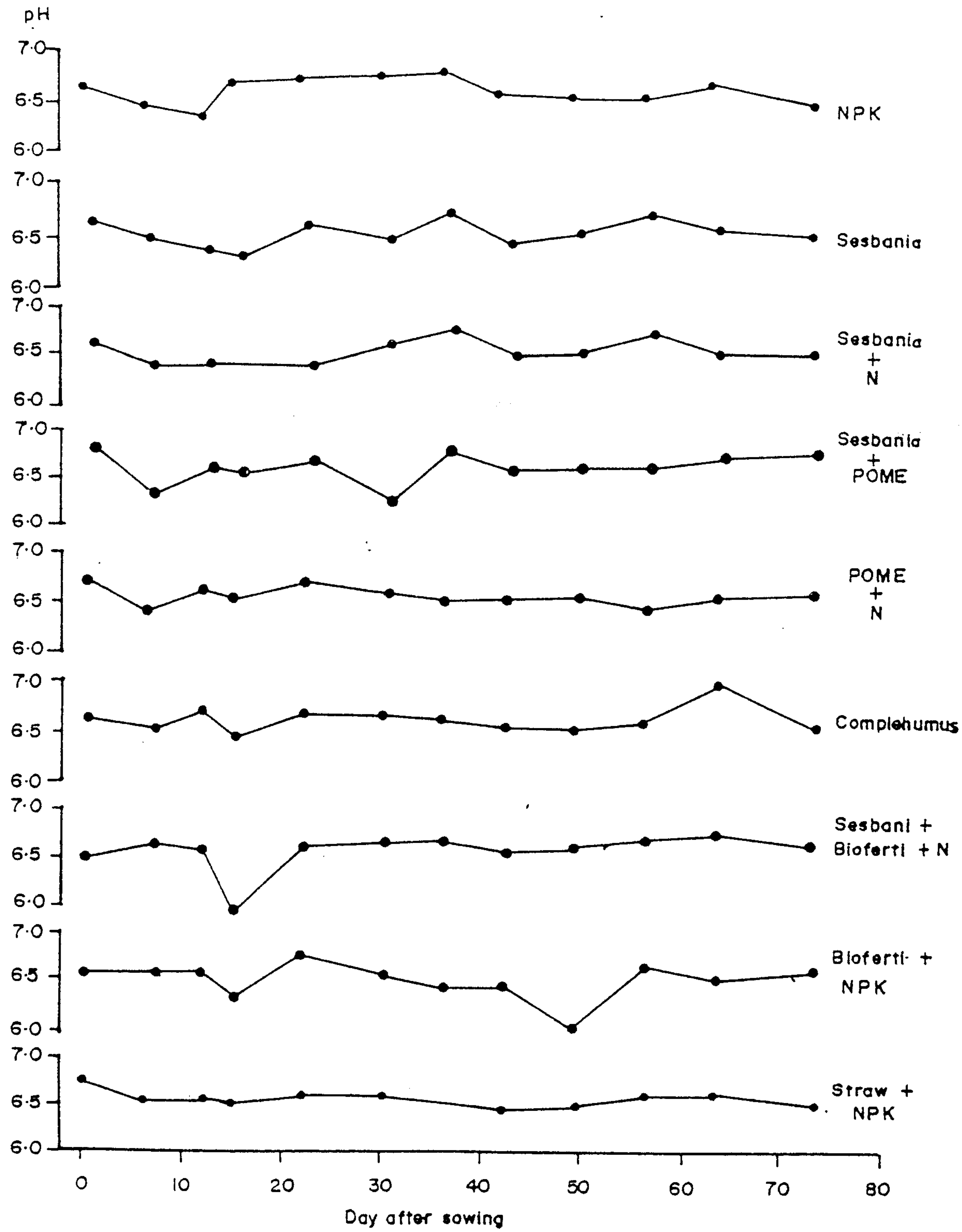

Figure 5. Changes in pH of rice soil with the addition of organic matter

for any of the organic amendments evaluated to cause a detrimental effect related to pH changes during the decomposition process.

6.3 Iron (II)

One of the most important chemical change that takes place upon flooding is the reduction of iron and the accompanying increase in its solubility. In addition the reduction of iron in a flooded soil is favoured by the presence of readily decomposable organic matter (Ponnamperuma, 1965). Plant analysis indicate high levels of iron in tissue of rice plants in the KADA region. Therefore it is necessary to have an understanding of the influence of organic matter additions on ferrous iron content of soils.

Table 7. Iron (II) content (ppm) at various growth stages

Treatment	0 DAS	30 DAS	56 DAS	74 DAS
NPK	274	360	268	474
Sesbania	219	321	264	435
Sesbania + N	309	356	295	530
Sesbania + POME	324	353	234	571
POME + N	323	368	361	524
Complehumus	315	394	349	622
Sesbania + Bioferti + N	299	331	346	477
Bioferti + NPK	ND	337	335	559
Straw + NPK	330	343	399	498

DAS: Days after sowing ND: Not determined

Irrespective of treatments there is a general increase in ferrous iron content with crop growth. Complehumus treated plots have distinctly higher amounts of iron (II) than others (Table 7). However there was no visual symptoms of iron toxicity in the plants from any of the plots.

6.4 Exchangeable Ammonium Nitrogen

The dynamics of exchangeable ammonium nitrogen varies with the treatments. There is an initial decline for all treatments followed by a rather rapid increase (Figures 6). The treatment with straw incorporation has the least initial decline (Figure 6-4). The exchangeable ammonium nitrogen content of soil 3 days after incorporation of organic amendments, prior to the decline, was more or less similar for all the treatment plots with a range of 34-46 kg NH_4^+-N/ha (Table 8). However at 6 days after incorporation (0 DAS) there were contrasting differences in the content of exchangeable ammonium nitrogen among treatments. Plots which had POME, Complehumus and Straw incorporation had higher contents in the range of 28-41 kg NH_4^+-N/ha than the NPK, Sesbania and Bioferti plots which had a range of 18-31 kg NH_4^+-N/ha. At 30 DAS, Complehumus, straw incorporated plots, Sesbania + POME and Sesbania + Bioferti plots had high exchangeable ammonium nitrogen contents of between 50-57 kg NH_4^+-N/ha. POME + Sesbania and Sesbania + Bioferti plots maintained a high level of exchangeable ammonium nitrogen in the soil even at the panicle initiation stage with an average value of 50 kg NH_4^+-N/ha. At 74 DAS there was a marked decline in contents of exchangeable nitrogen for all the plots with a range of 6-15 kg NH_4^+-N/ha.

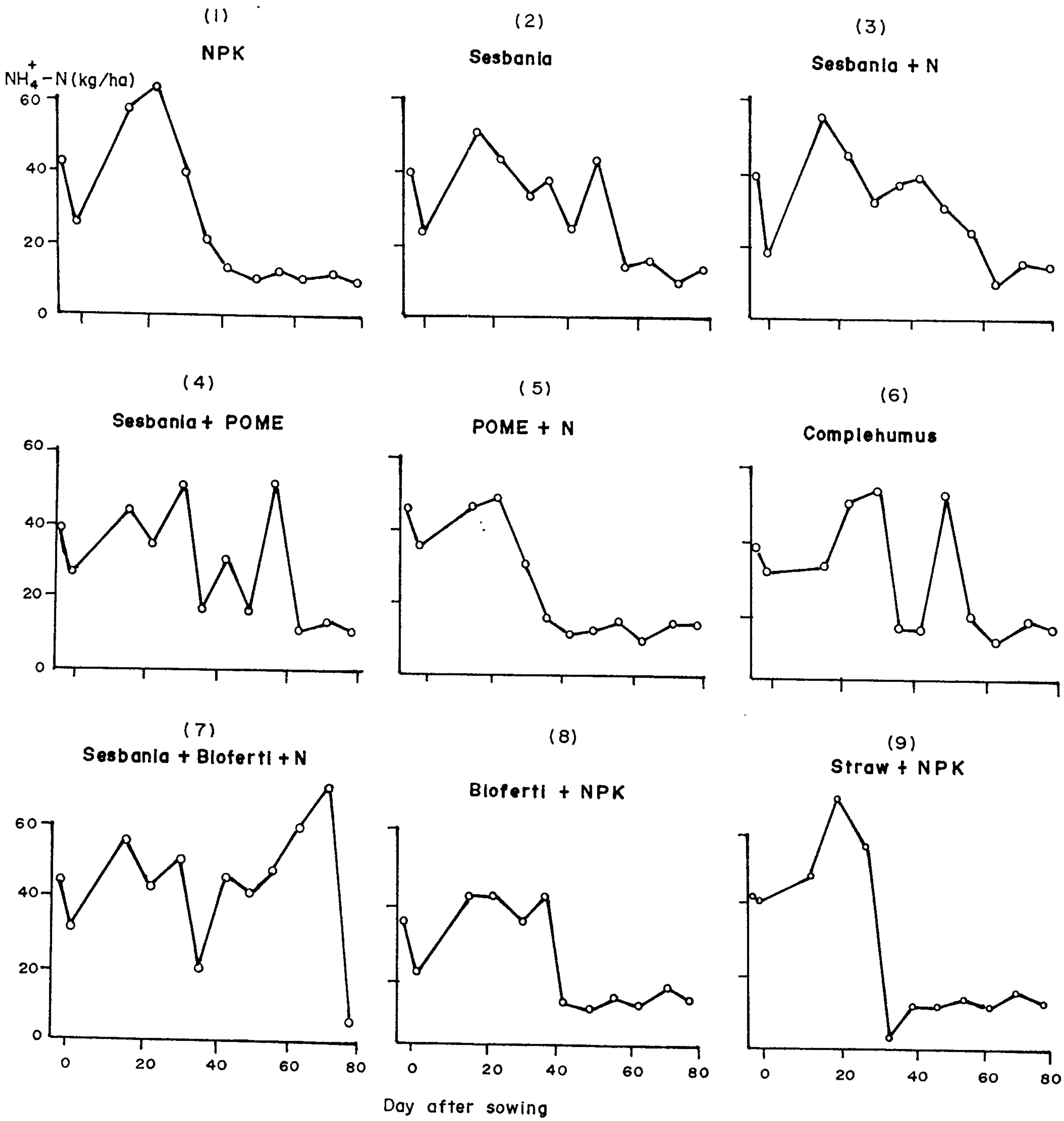

Figure 6. Ammonium nitrogen dynamics in rice soil with various organic matter treatments

Table 8. Exchangeable NH_4^+-N (kg/ha) in soil at various growth stages

Treatment	-3 DAS	0 DAS	30 DAS	56 DAS	74 DAS
NPK	42.01	25.15	39.60	12.03	9.57
Sesbania	40.16	23.25	34.24	14.27	13.94
Sesbania + N	39.04	18.39	32.29	24.46	14.93
Sesbania + POME	39.83	27.83	52.42	52.91	11.84
POME + N	46.38	35.95	30.11	15.17	14.11
Complehumus	36.47	29.55	53.25	17.12	14.52
Sesbania + Bioferti + N	44.59	31.35	50.49	48.79	5.88
Bioferti + NPK	34.13	19.96	33.66	13.00	12.59
Straw + NPK	42.24	41.63	56.78	13.52	11.78

Comparing the ammonium nitrogen dynamics for the various treatments it is evident that the NPK treatment has a distinct single peak occurring at about 20 DAS and the exchangeable NH_4^+-N content at this stage is about 60 kg NH_4^+-N/ha (Figure 6). A similar trend is also observed for the treatments straw + NPK (Figure 6-9) and POME + N (Figure 6-5) with a peak release of soil exchangeable ammonium nitrogen of 70 and 50 kg NH_4^+-N/ha. Beyond 25 DAS, a rapid decline in ammonium nitrogen content for all three treatments were observed, reaching a steady value of about 10 kg NH_4^+-N/ha from 40 DAS. In contrast, the treatments with Sesbania (Figure 6-2), Sesbania + N (Figure 6-3), Sesbania + POME (Figure 6-4), Complehumus (Figure 6-6), Sesbania + Bioferti + N

(Figure 6-7) and Bioferti + NPK (Figure 6-8) have several peaks indicating increases in soil exchangeable ammonium nitrogen concomitant to the progressive decomposition of the organic matter with time. Except for the treatment Sesbania + Bioferti + N (Figure 6-7), the remaining treatments reach a steady low value for exchangeable ammonium nitrogen at about 60 DAS. The treatment Sesbania + Bioferti + N has a peak value occurring at about 70 DAS. It is hypothesized that an organic matter source with a delayed release as obtained in the treatment of Sesbania + Bioferti + N would be most beneficial as it is at the later growth stages of rice that the content in the soils become limiting and does not match the crop needs (Figure 7-4). The same phenomenon is observed for Sesbania at 50 DAS and Sesbania + POME at 60 DAS in comparison with NPK treatments (Figure 7-1 and 7-2). The organic matter status of soil did not show any lasting increase and has to be supplemented regularly to maintain a high level.

6.5 Grain Yield

The grain yield was significantly different among the treatments. Yields were lowest for plots which received no inorganic fertilizer but had only incorporation of Sesbania (Tables 9 and 10). Plant growth throughout the growing season was poor and exhibit nitrogen deficiency symptoms. It is evident that the incorporation of Sesbania at about 8 t/ha fresh weight basis is insufficient to sustain adequate growth and yield. It has to be augmented with inorganic fertilizer. An application of 50 kg N/ha at the panicle initiation stage increased yield by only 0.2 t/ha at Pasir Putih as the stunting was too severe for any remedial action. In Chempaka however the addition of N to Sesbania enhanced the yield

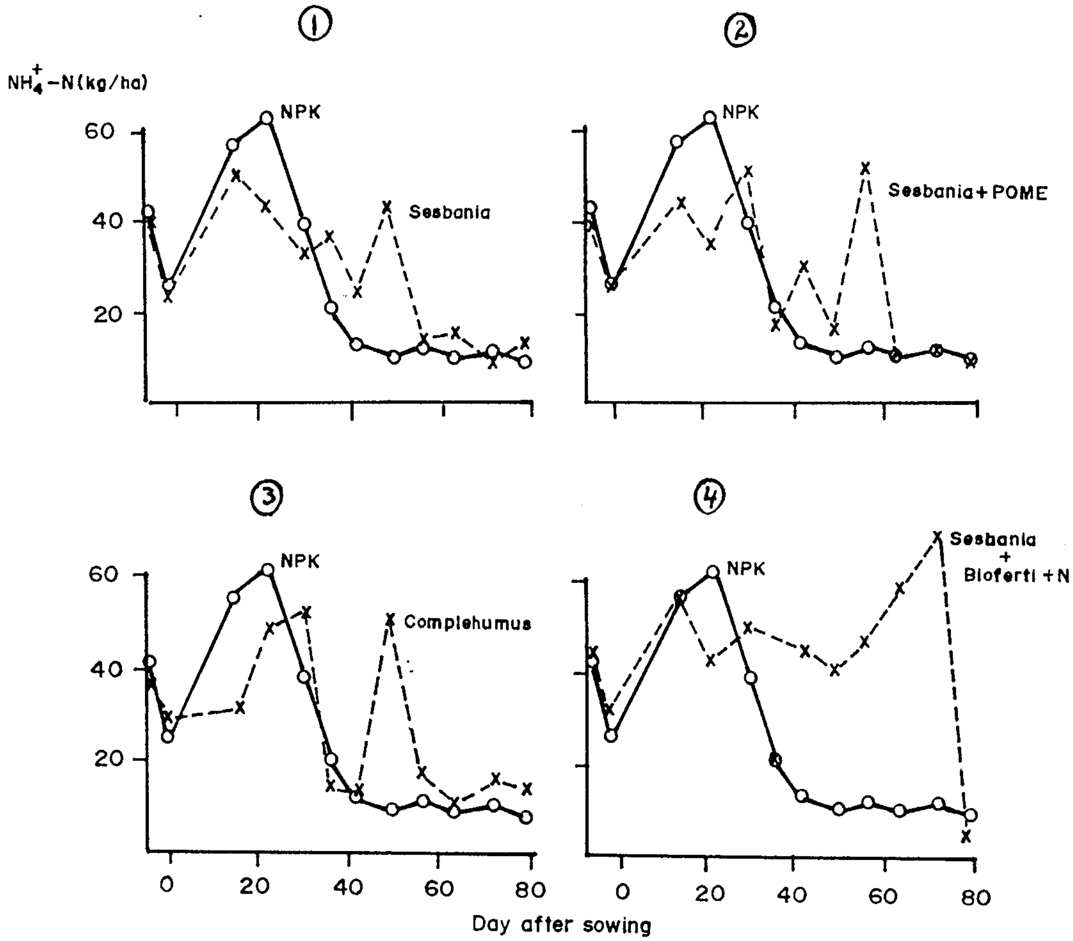

Figure 7. Comparison of soil exchangeable ammonium nitrogen with addition of organic matter and NPK

Table 9. Grain yield with the use of organic amendments in Pasir Putih soil series

Treatment	Grain yield (kg/ha)
1. NPK	4035
2. Sesbania	3413
3. Sesbania + N	3650
4. Sesbania + POME	3822
5. POME + N	4230
6. Complehumus	4778
7. Sesbania + Bioferti + N	3914
8. Bioferti + NPK	4138
Mean	3997
C.V.%	9.0

ANOVA for grain yield

Source	d.f.	S.S.	F-value
Replicate	3	69729.75	0.18 n.s.
Treatment	7	4735449.00	5.26**
Error	21	2703349.25	
Total	31	7508528.00	

**: significant at the 1% level; n.s.: not significant; Trial was conducted at Jerus; Soil series: Pasir Putih

Table 10. Grain yield with the use of organic amendments in Chempaka soil series

Treatment	Grain yield (kg/ha)
1. NPK	5908
2. Sesbania	4038
3. Sesbania + N	4989
4. Sesbania + POME	4650
5. POME + N	5245
6. Complehumus	5810
7. Sesbania + Bioferti + N	5353
8. Bioferti + NPK	6360
9. Straw + NPK	6192
Mean	3997
C.V.%	6.83

ANOVA for grain yield

Source	d.f.	S.S.	F-value
Replicate	2	607866.96	2.24 n.s.
Treatment	8	13763729.19	12.68**
Error	16	2171435.04	
Total	26	16543031.19	

**: significant at the 1% level; n.s.: not significant; Trial was conducted at Perol; Soil series: Chempaka by about 0.9 t/ha. At both the locations, highest yields were obtained with additions of organic sources. In the coarse textured soil of Pasir Putih series, the application of Complehumus gave a mean yield of 4778 kg/ha (Table 9). At the location of Chempaka series, a fine textured soil, highest yields were obtained with the treatment of Bioferti + NPK with a mean yield of 6360 kg/ha (Table 10). At this location, the treatment of Straw + NPK had a mean yield of 6192 kg/ha while the grain yield with NPK applied in three split doses was 5908 kg/ha. The study proved that organic based fertilizer or organic matter additionals have the potential to improve yields to higher levels than could possibly be achieved with inorganic fertilizers alone.

The rice yield with various organic matter treatments in the two seasons is illustrated in Figure 8. It is clear that the treatments with addition of Complehumus, POME, Straw and Bioferti generally had a higher yield than NPK. The further studies were therefore concentrated on the use of POME, Straw and Bioferti (effective microorganisms).

6.6 Effect of Green Manure (*Sesbania rostrata*)

Sesbania rostrata seeds were brought in from IRRI in 1992 for the studies. This was the first time *Sesbania rostrata* was introduced into the rice fields of Malaysia.

In general, studies show that the legume *Sesbania rostrata* is fast growing and at a seed rate of 50 kg/ha can attain a mean plant height of 108 cm and produce a fresh weight of 60 t/ha in 45 days. The legume is able to withstand flooded conditions and can nodulate profusely on the stems. The nitrogen concentration in plant, on a dry matter basis, was 2% at 45 days with the total nitrogen content in plant being 200 kg/ha. Assuming that

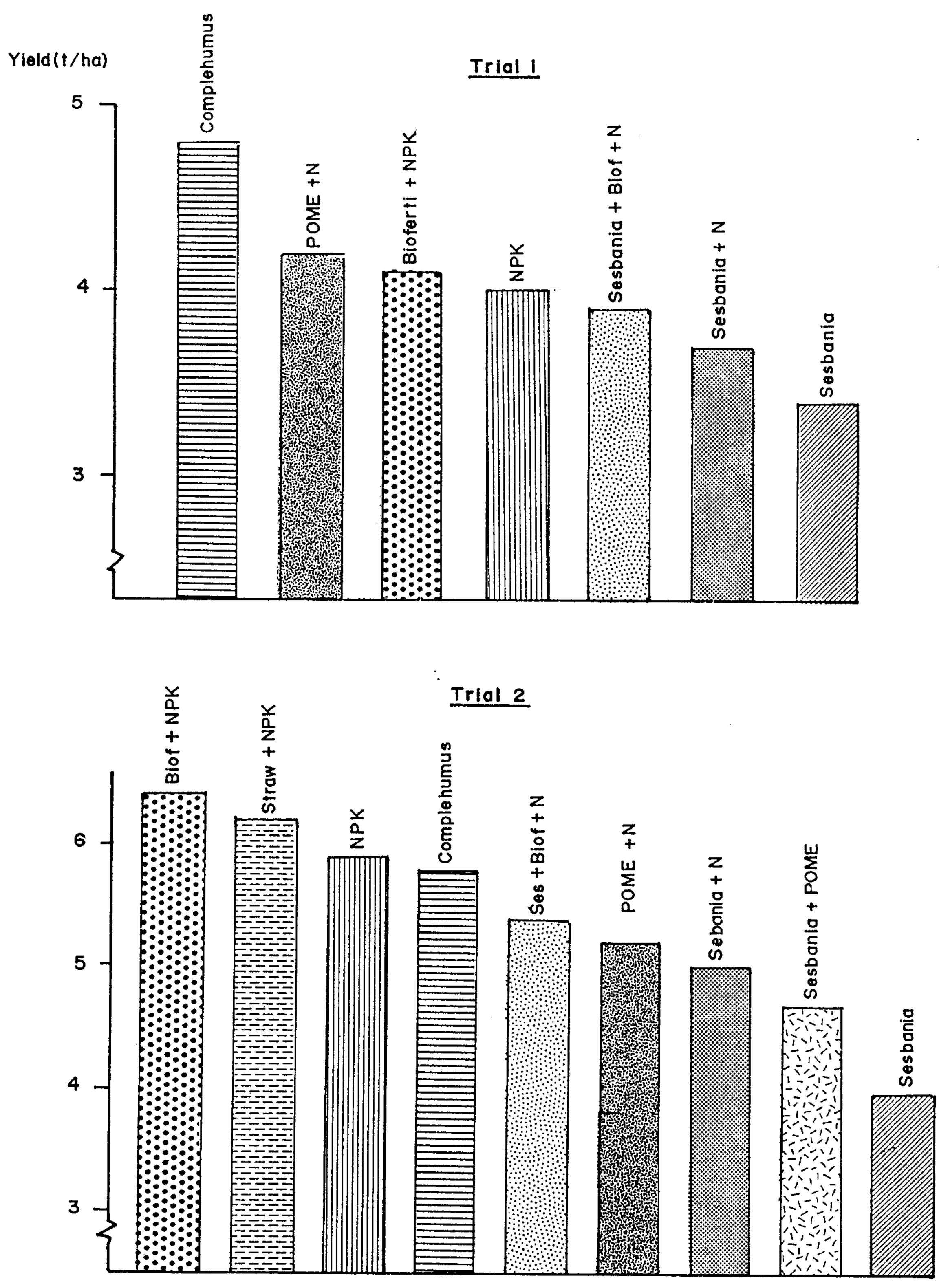

Figure 8. Rice yield with various organic matter treatments in comparison with NPK in KADA

50% to 80% of the nitrogen accumulated in the legume originates from biological nitrogen fixation (Fried *et al.*, 1983), it would mean that the crop can provide 100 to 160 kg/ha of nitrogen. Studies by Meelu and Morris (1988) have shown that basal fertilizer can be replaced by legume green manure but it is necessary to apply a top-dressing of nitrogen in order to attain maximum yields.

Nitrogen fixation by Sesbania was determined in MADA, KADA and PBLS following the technique of acetylene reduction assay. Rhizobial innoculum was not used with the Sesbania seeds. The measurement of growth parameters and nitrogen fixation was done when the Sesbania plants were 55 days old, prior to slashing and incorporation into soil. In KADA the growth of Sesbania in the first season was very poor compared to the second season's growth. The number of stem and root nodules per plant was 33 ± 3 and 14 ± 1 respectively for stem and root in the first season. In the subsequent season, higher values were obtained. The number of nodules were 128 ± 5 and 31 ± 3 for stem and root respectively. A similar trend was shown in the other growth parameters. The dry weight of stem and leaves per plant in the first season was 0.41 ± 0.03 and 0.14 ± 0.05 g respectively and in the second season it was 1.75 ± 0.14 and 1.24 ± 0.09 g respectively. There was also a notable increase in stem nodule dry weight to $14.48 \pm 0.82 \times 10^{-2}$ g in the second season from $3.30 \pm 0.37 \times 10^{-2}$ g in the first season. Similarly root nodule dry weight increased from $1.93 \pm 0.02 \times 10^{-2}$ g in the first season to $11.69 \pm 1.02 \times 10^{-2}$ g in the second season. The generally better performance in the second season is attributed to an increase in indigenous innoculum source after the first season cultivation of Sesbania.

Nitrogen fixation for the first and second season was $492 \pm 58 \times 10^{-9}$ and $216 \pm 43 \times 10^{-9}$ moles/hr/plant respectively. The better growth of Sesbania in the second season did not result in higher nitrogen fixation.

In MADA, growth of Sesbania was considerably less in the second season and is manifested in all the growth parameters measured, particularly root nodule number was drastically reduced. However, nitrogen fixation was $1148 \pm 114 \times 10^{-9}$ moles/hr/plant, being markedly higher than in KADA.

The rice yield with incorporation of Sesbania in comparison with NPK in MADA over a period of three seasons is illustrated in Figure 9. It is evident that in the first season the yield with Sesbania is lower than NPK by about 0.8 t/ha, but there is a progressive increase in yield over the second and third seasons. The addition of a top-dressing of nitrogen to Sesbania can certainly increase the yield by about 0.2 to 0.9 t/ha as shown in Tables 9 and 10.

The rice yield with the use of Sesbania in KADA in two seasons is illustrated in Figure 8. It is evident that the use of Sesbania alone had the lowest rice yield in the two seasons. However, the yield increased progressively with the additions of Sesbania + Nitrogen or Sesbania + POME or Sesbania + Bioferti + Nitrogen. This shows that Sesbania can only be an effective rice yield enhancer if supplemented by other organic matter sources or nitrogen. The incorporation of 5-7 t/ha of Sesbania is insufficient to meet the needs of the rice crop, and the total organic matter input with additions from other sources has to be increased to about 15-20 t/ha.

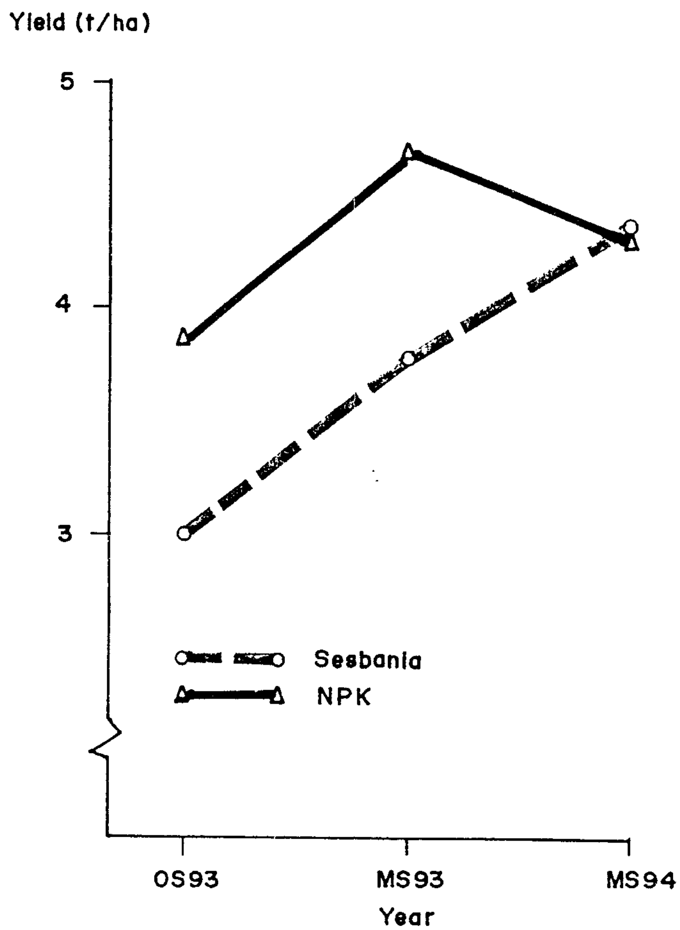

Figure 9. Rice yield with Sesbania compared with NPK in MADA

6.7 Effect of Palm Oil Mill Effluent (POME)

The field trial was conduct adopting a randomized complete block design with factorial combinations of six levels of organic matter incorporation (%C) and three nitrogen levels in three replicates. Organic matter treatments were instituted only in the first season with the intention of assessing residual effects of organic matter incorporation in the subsequent seasons. Nitrogen fertilizer was applied at each planting season at their respective treatment rates in two split applications, 50% at 14 DAT and 50% at 42 DAT. All plots received 40 kg P_2O_5/ha and 40 kg K_2O/ha. 28 day old seedlings of variety MR 81 was transplanted at a spacing of 20cm x 20cm after incorporation of the POME. The plot size used was 6m x 4m. Nitrogen test rates were 0, 60 and 120 kg/ha. POME which had about 60% moisture content was tested at equivalent rates required to raise the soil organic carbon content by 0.5, 1, 2, 3 and 4%. The actual rates of POME applied was 0, 19.2, 38.4, 76.8, 115.2 and 153.6 t POME/ha.

Table 11 gives the grain yield results of the study for seven consecutive rice growing seasons. The main effects of POME, NPK, and POME + NPK for seven seasons are illustrated in Figure 10. It is evident that the application of POME in the first season resulted in a significantly higher yield in comparison with NPK, and a higher yield than POME + NPK treatments. In the second season the residual effect of POME had a marginally higher yield than NPK, and POME + NPK treatments. In the following third to seventh seasons the residual effect of POME diminished and yields were well below that of NPK, and POME + NPK treatments. It is interesting to observe that POME + NPK treatment (POME applied only in first season) had a significantly higher yield in

Table 11. Mean yield of rice (t/ha) with N + POME treatments over seven seasons

Treatment		Season						
N (kg/ha)	POME (%C)	1	2	3	4	5	6	7
0	0.0	5.4	5.0	4.5	4.4	3.6	4.5	4.8
0	1.5	6.2	5.0	4.3	4.1	3.9	4.7	4.9
0	1.0	9.3	4.5	4.1	4.3	3.8	4.9	4.6
0	2.0	6.4	5.5	4.9	4.7	4.1	4.6	4.7
0	3.0	6.7	5.4	4.6	4.7	4.1	5.0	4.7
0	4.0	6.0	5.2	5.6	5.3	4.6	5.1	5.6
60	0.0	5.7	5.1	5.4	5.0	4.8	4.9	5.0
60	0.5	6.3	5.2	5.4	5.2	4.3	5.4	5.2
60	1.0	6.2	5.7	5.5	5.2	4.5	5.3	5.3
60	2.0	6.2	5.5	5.5	5.2	4.8	4.9	5.2
60	3.0	6.4	5.5	5.4	5.2	4.7	5.2	5.2
60	4.0	6.0	5.3	5.8	5.2	4.9	5.3	5.1
120	0.0	4.9	5.3	5.5	5.4	4.7	5.2	5.5
120	0.5	6.3	5.1	5.3	5.5	4.7	5.3	5.5
120	1.0	6.2	5.1	5.8	5.2	4.9	5.2	5.7
120	2.0	5.8	5.0	5.8	5.3	4.9	5.5	5.6
120	3.0	5.9	5.3	5.8	5.3	5.0	5.2	5.1
120	4.0	5.6	4.4	5.7	5.4	5.0	5.1	5.4

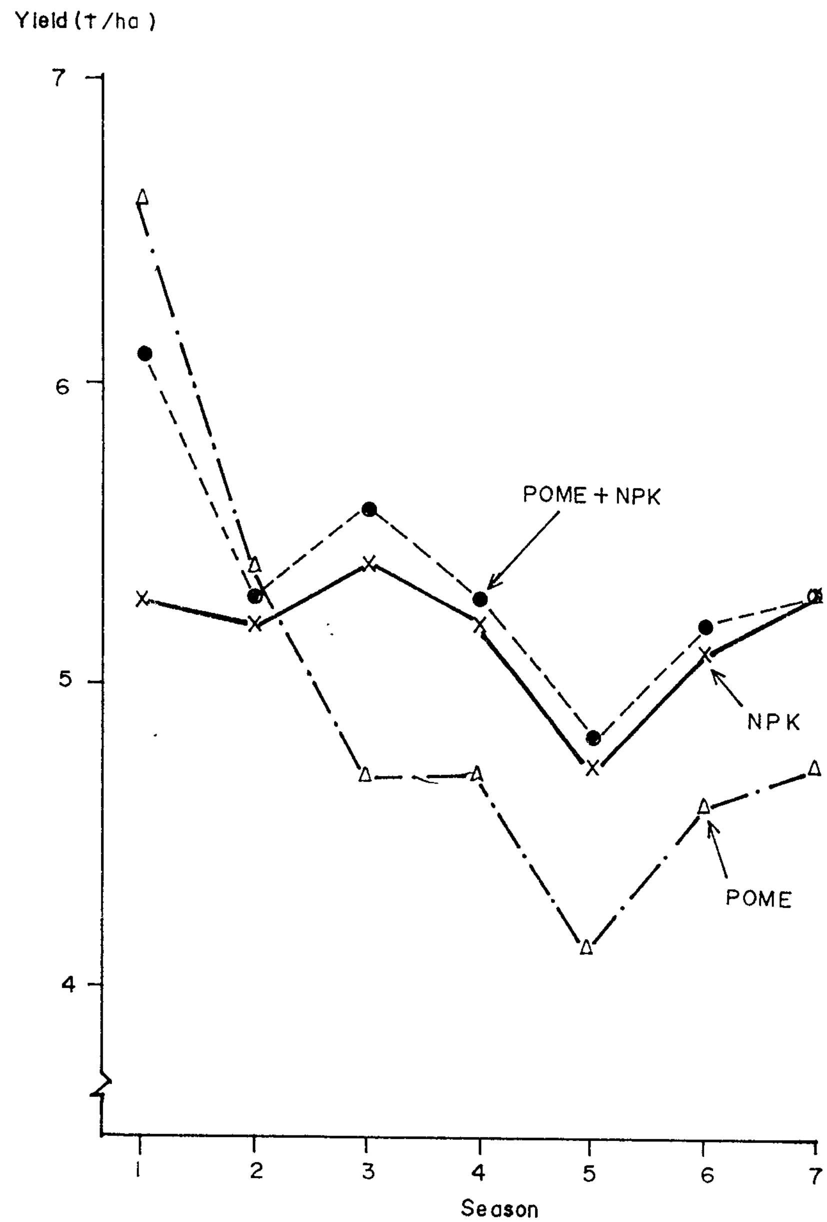

Figure 10. Residual effect of POME over seven seasons

comparison with NPK in the first season and maintained a marginally higher yielder than NPK in the following seasons until the seventh season. The study clearly shows that yield can be enhanced by using POME in rice and it has the potential of replacing NPK.

6.7.1 Response by Seasons

The first season of POME incorporation had significant influences on grain yield. The yield gain averaged over N rates with POME application was 848 $\pm$ 112 kg/ha. In contrast, when averaged over POME rates, there was no favourable response to N. It is plausible that the nitrogen mineralized from the decomposition of POME was sufficient. With 0 N and 60 N, yields exceeding 6 t/ha were obtained with all rates of POME except that of 4% C. At low levels of N, rice yield increased with POME rates up to 3% but decreased at 4%. At high level of N, rice yields were suppressed when POME level was increased above 0.5% C which indicated that POME was able to supply N for rice growth and luxurious amount of N at 4% suppressed yield (Figure 11-1).

In season 2, averaged over N rates, POME at 4% continued to have lowest yield and was significantly lower than that obtained at 3% C (Figure 11-2). The residual effect of POME at 4% C applied in the first season still provided excessive nitrogen. Though the POME rates 0.5, 1, 2, 3 and 4% C did not have significant favourable residual response, the yield gain with 2 and 3% C was about 0.2 t/ha. Averaged over POME rates, the cumulative application of 60 kg N/ha provided a significant yield increase of 0.4 t/ha.

The residual response to POME at 4% C and response to cumulative applications of 60 and 120 kg N/ha was pronouncedly expressed in the third season (Figure 11-3). There

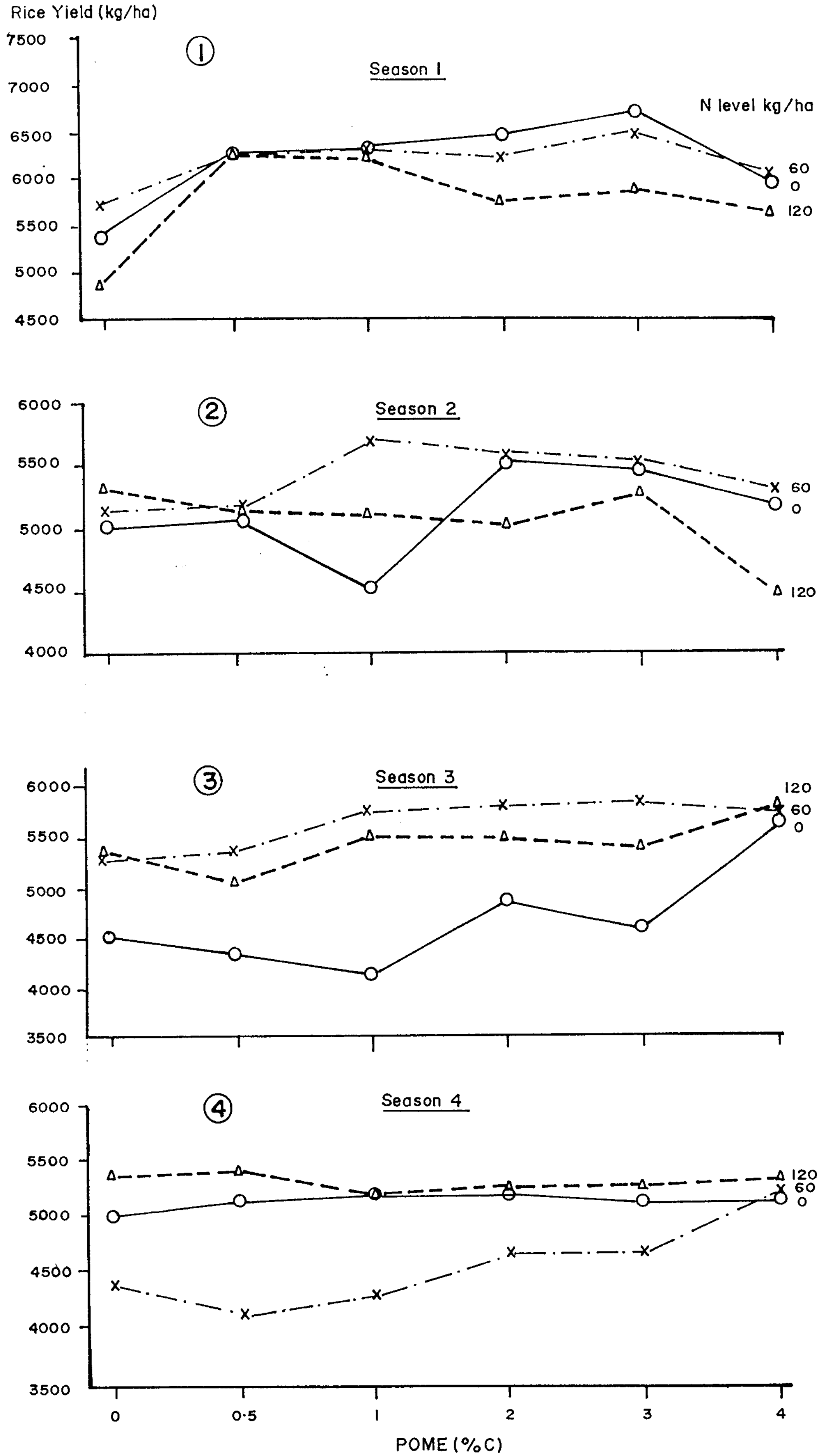

Figure 11. Residual response to POME to cumulative applications of nitrogen - Season 1 to 4

was significant POME*N interaction. There was no residual response to POME at 0.5% C. The residual effect to POME at 1, 2 and 3% C and cumulative non-application of POME was not significantly different. Averaged over N rates, the yield increase with residual POME at 4% C was 0.6 t/ha.

The trend of residual response to POME application in the fourth season was similar to the third season except non-significance for yield response between levels of POME at 2, 3 and 4% C (Figure 11-4). The yield increase for these levels of POME and to N levels was 0.2 to 4 t/ha and 0.6 to 0.9 t/ha averaged over N rates and POME rates respectively.

The residual yield response to POME at 2 and 3% C was significantly lower than 4% C in the fifth season (Figure 12-5). The yield increase with 2 and 3% was only 0.2 t/ha while that due to 4% C was 0.4 t/ha. Generally there was only a better residual response to POME than in the previous two seasons. The mean yield gain to POME in the fifth season was 180 $\pm$ 61 kg/ha and that in the third and fourth season was 136 $\pm$ 66 and 126 $\pm$ 62 kg/ha respectively. Cumulative application of inorganic fertilizer provided a significant yield increase of 0.6 and 0.8 t/ha at 60 and 120 kg N/ha respectively.

The sixth season results showed non significant yield response to both POME and N rates (Figure 12-6). The season had exceptionally high experimental error with a coefficient of variation at 17.95%. However, the yield trend continued to be maintained with highest yield obtained for residual POME effect at 4% C and to cumulative application of inorganic nitrogen fertilizer. The yield increase was 0.3 and 0.4 t/ha averaged for POME and N rates respectively.

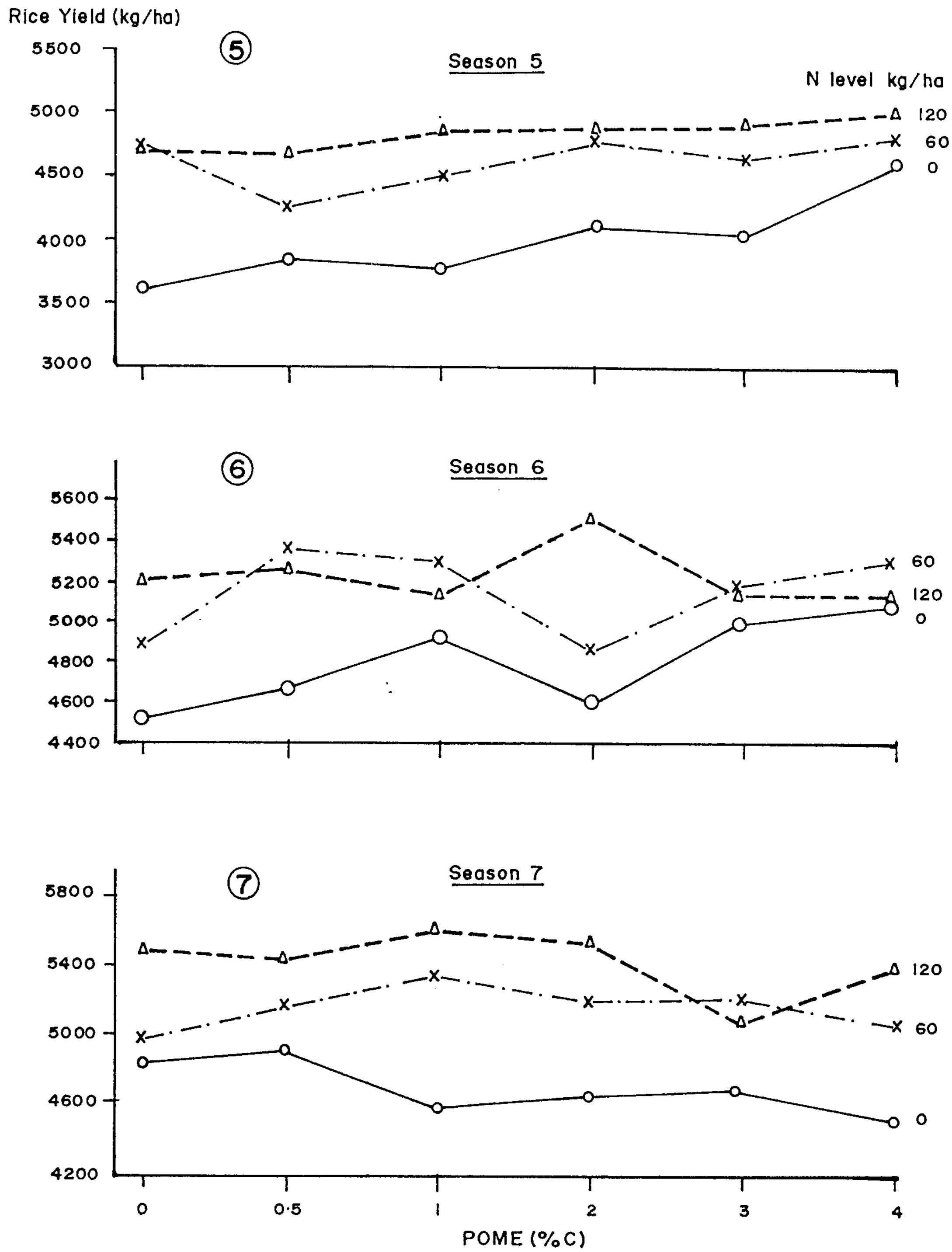

Figure 12. Residual response to POME to cumulative applications of nitrogen - Season 5 to 7

Irrespective of POME rates there was no significant yield difference in the seventh season. Averaged over N rates the residual response to POME at 4% C declined to 0.2 t/ha. Nitrogen response was markedly expressed with yield increases of 0.3 and 0.6 t/ha to 60 and 120 kg N/ha respectively (Figure 12-7).

Averaged over the seven seasons and N rates, the relationship of yield gain with POME rates (Figure 13) using a negative exponential function (Mitscherlich's) following NLIN procedure in SAS was as follows:

$$YG = 325.51839(1-e^{-0.8138*POME})$$

where YG = Yield gain in kg/ha;

POME = Rate of POME in terms of %C increment desired.

Following the relationship above, the averaged maximum yield gain was 326 kg/ha for a season's application followed by residual effects for six consecutive seasons. The study clearly shows the retention capacity of organic matter in the rice soil and the following conclusion are drawn:

(i) The application of POME in the first season produced significant yield increases even at the lowest level of POME at 0.5% C. The yield increase was 848 $\pm$ 112 kg/ha.

(ii) Inorganic fertilizer application can be reduced by 50% in the first season of POME application and in the subsequent season (season 2) and thereafter normal N rates should be resumed.

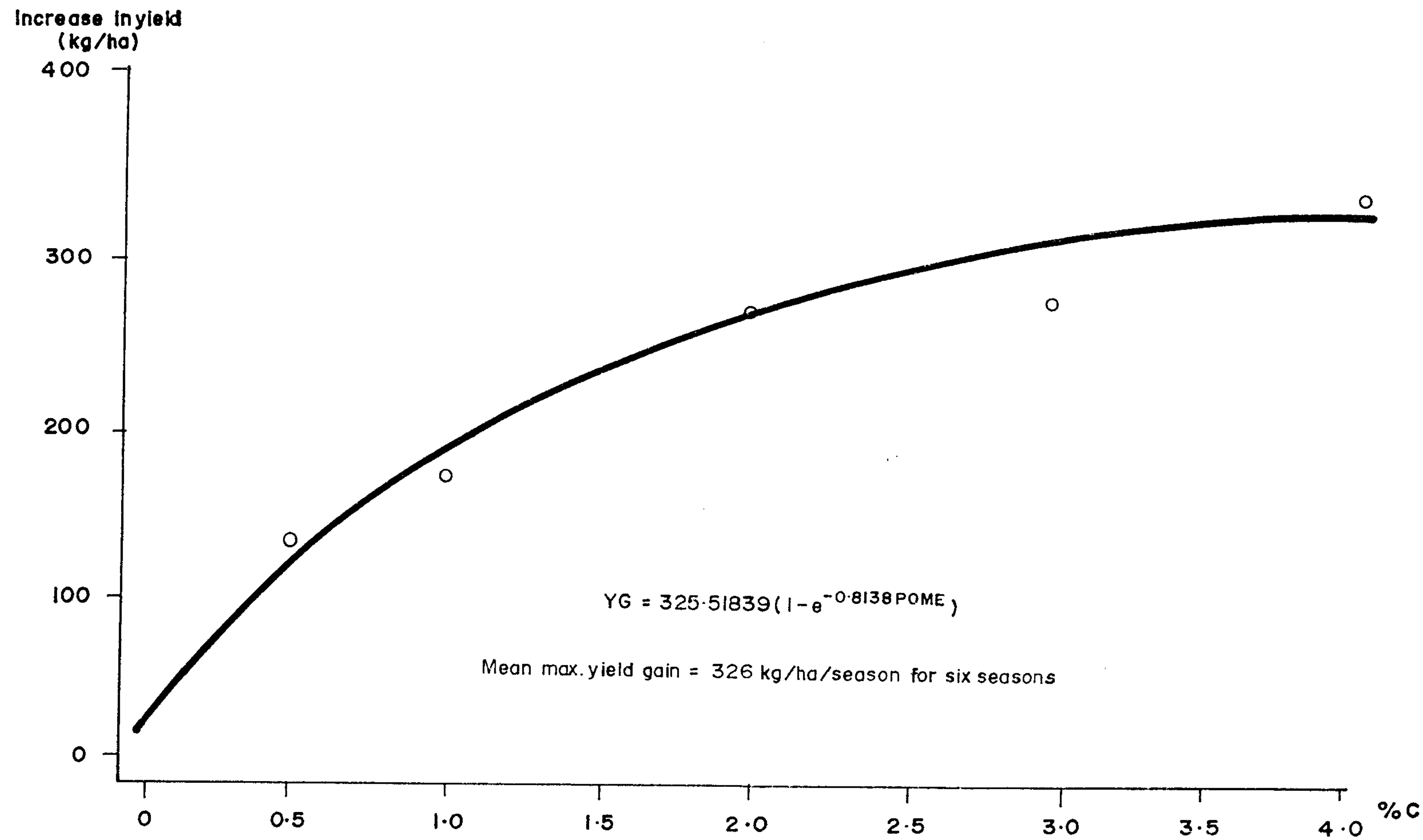

Figure 13. Relationship of yield gain to POME rate

(iii) There is no residual response for POME at rates less than or equal to 1% C.

(iv) The residual response of POME at 2 and 3% C though not significantly different from without POME application is 0.2 to 0.3 t/ha and the effect is realized for 5 consecutive seasons (from season 2 to season 6).

(v) POME rates at 4% are excessive and caused a decline in grain yield in the season of application and in the following season (residual effect).

(vi) Residual response to POME at 4% C was significantly higher than the other rates only in the third season with a yield increase of 0.6 t/ha and the trend was continued in the subsequent seasons though not significantly different from 2 and 3% C levels.

(vii) The mean residual effect of POME resulted in a maximum yield gain of 326 kg/ha for six consecutive seasons.

6.8 Effect of Rice Husk and Rice Straw

The experiment was conducted over two consecutive rice growing seasons with variety MR 84 transplanted at a spacing of 20cm x 20cm. The nitrogen rate tested was 87 kg N/ha for all treatments except control (0 N). Phosphorus as triple superphosphate and potash as muriate of potash was applied at the rate of 40 kg P_2O_5/ha and 40 kg K_2O/ha respectively. The following treatments were evaluated in the experiment:

1. Control.
2. Urea supergranule (USG). Point place at 10-12cm depth at 2 days after transplanting (DAT).

3. Prilled urea (PU). Broadcast into standing water of 5-10 cm. 44 kg N/ha at 14 DAT and 43 kg N/ha at 42 DAT.

4. Petronas granular urea (PGU), 5.6 mm size. Broadcast into standing water of 5-10 cm as in (3).

5. Rice husk + PGU. Rice husk at 8 t/ha was incorporated into soil one week before transplanting. PGU applied as in (3).

6. Straw + PGU. Straw was applied at 5 t/ha, one week before transplanting. PGU applied as in (3).

7. PGU. 2/3 basal broadcast and incorporated with rake two days before transplanting. 1/3 broadcast into standing water at 42 DAT.

Table 12. Effect of nitrogen sources and amendments on grain yield

Treatment	Grain yield (kg/ha)	
	Season 1	Season 2
1. Control (0 N)	4204 d	2252 c
2. USG (Deep placement)	5137 c	3141 ab
3. PU	5329 bc	3203 ab
4. PGU (Broadcast)	5606 bc	3462 ab
5. PGU + Rice husk	5814 ab	3201 ab
6. PGU + Rice straw	6289 a	3780 a
7. PGU	5333 bc	2839 bc

In both seasons, PETRONAS granular urea (5.6 mm), a locally manufactured urea combined with rice straw gave highest yield (Table 12). In season 1, it had significantly higher yields than USG, PU and PGU either broadcast or incorporated. The trend was similar in the second season though the yields were not significantly different except for PGU incorporated which had significantly lower yields. The yield enhancement due to use of rice straw + PGU over the conventional practice of PU application is in the range of 0.6 to 1.0 t/ha (Figure 14).

The following conclusions were drawn from the study:

(i) The merits of deep placement of USG was not manifested in the study.

(ii) The field experiment illustrated the superiority of PGU over PU and USG.

(iii) PGU + Straw is a promising avenue for rice yield maximization.

(iv) The use of rice husk did not give a consistent yield increase as obtained from rice straw.

(v) The relative yield increase over control for immediate effect (application in the first season) and for cumulative effect (continued application in the second season) was 50% and 68% respectively for PGU + rice straw and 27% and 42% for PU.

Rice straw has potential to be used as organic fertilizer with special field management techniques to allow it to decompose rapidly. It was observed that straw when well distributed in the field and in contact with soil without complete flooding resulted in 60-

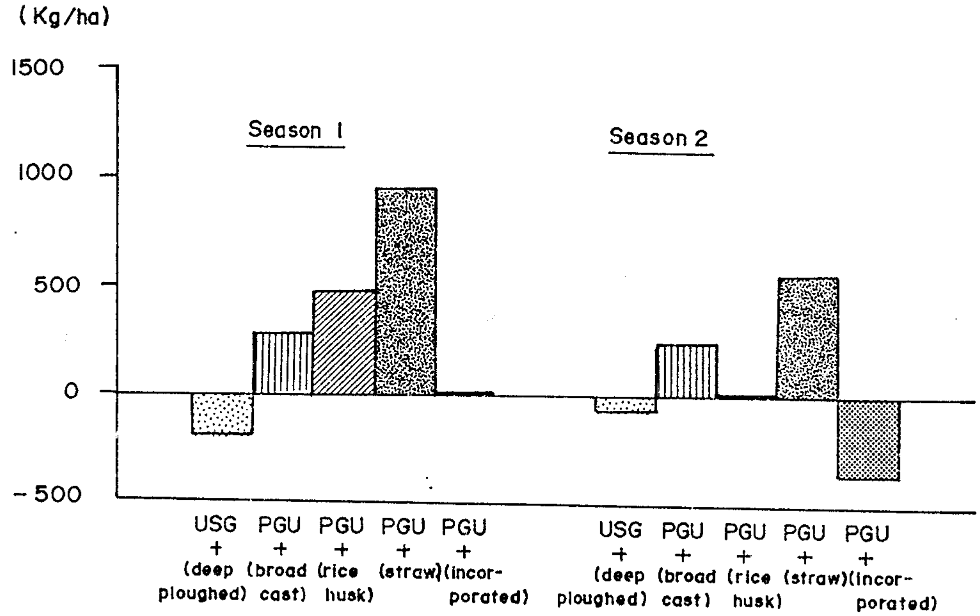

Figure 14. Yield enhancements of urea forms with rice husk and straw

80% decomposition within 3 weeks of application. The use of Effective Microorganisms sprayed on the straw can further accelerate the decomposition of straw.

6.9 Studies on Effective Microorganisms (EM)

The concept of inoculating soils and plants with beneficial microorganisms to create a more favorable microbial environment for plant growth has been known for a very long time. However, the technology behind this concept and its practical application have now been greatly advanced by Prof. Teruo Higa, at the University of the Ryukyus in Okinawa, Japan.

Effective microorganisms (EM) is made up of mixed cultures of naturally occurring species of organisms that are found in natural environments worldwide. EM is special because Prof. Higa has isolated and selected different microorganisms for their beneficial effects in soils and plants, and has found organisms that can coexist in mixed cultures and are physiologically compatible with one another. When these cultures are introduced back into the natural environment, their individual beneficial effects are greatly magnified in a synergistic fashion.

The EM used in the studies was EM4. EM4 contains more than 5 families, 10 genera and 80 species of coexisting microorganisms. EM4 which was used in the studies consists mainly of Lactobacillus (lactic acid bacteria), with smaller numbers of photosynthetic bacteria, streptomyces species, and yeasts. EM4 enhances the decomposition of organic wastes and residues, increases the availability of nutrients to plants, and suppresses the activity of pathogenic microorganisms.

The field trials on rice with the various organic fertilizers including EM4 were started in the off-season 1993. The trials were carried out in the rice granaries Muda and PBLS. The plot size was 5m x 5m. A randomized complete design was used with four replicates. The rate of application of EM4 was at a dilution rate of 1:1000. Plant growth measurement, components of yield and grain yield records were taken.

The effect of EM4 on the yield of rice in Muda for three seasons is given in Table 13. In the first season there was a 15% increase in yield with the addition of EM4 to the POME + NPK treatment followed by a 7% increase in the second season and 5% decrease in the third season. The progressive decline in yield with application of EM4 from +15% to -5% may be due to the progressive build up of residual POME in the soil. In the other organic matter treatments, the addition of EM4 to straw, sarcom (composted rice husk) caused a decline in yield of 2 to 5%. The application of EM4 to *Sesbania rostrata* had only a very small effect on the yield with -2% in the first season, +2% in the second season and +3% in the third season. It would seem that the effect of EM4 depends on the type of organic matter used probably related to the C/N ratio and management of the organic matter in the soil. The C/N ratio of POME is lower at 8.5 compared to sarcom and straw at 40 and 80 respectively. *Sesbania rastrata* also has a low C/N ratio of 4.79 - 6.18, but it is worked into the soil just before transplanting of the rice crop and it may have some problems in decomposition under the flooded conditions. The yield trend in the three seasons with EM4 applications is illustrated in Figure 15. There is an overall positive effect of EM4 in all the organic matter treatments except POME which show an increasing yield trend (Samy, *et al.*, 1996).

Table 13. Effect of EM4 on the yield of rice in Muda

Treatment	Yield (kg/ha					
	O.S. 1993	%	M.S. 1993	%	M.S. 1994	%
Straw + NPK	3864 a	0	4393 a	0	4356	0
Straw + NPK + EM4	3523 ab	-9	4598 a	+5	4469	+3
POME + NPK	3409 ab	0	4456 a	0	4636	0
POME + NPK + EM4	3916 a	+15	4787 a	+7	4393	-5
Sarcom + NPK	3730 a	0	4448 a	0	4284	0
Sarcom + NPK + EM4	3523 ab	-6	4518 a	+2	4351	+2
Sesbania + N	3499 b	0	4310 a	0	4649	0
Sesbania + N + EM4	3418 ab	-2	4390 a	+2	4799	+3
Mean	3610		4488			
CV(%)	10.0		9.0			

Means having a letter in common are not significantly different at the 5% level Duncans' Multiple range tests.

Straw: 5 t/ha, NPK: 80, 30, 20 kg/ha, POME: 5 t/ha, Sarcom: 5 t/ha, sesbania seed rate at 50 kg/ha.

The effect of EM4 on the grain yield of rice in PBLS over 3 seasons is given in Table 14.

The effect of EM4 on straw in Tanjung Karang was clearer with a progressive increase in

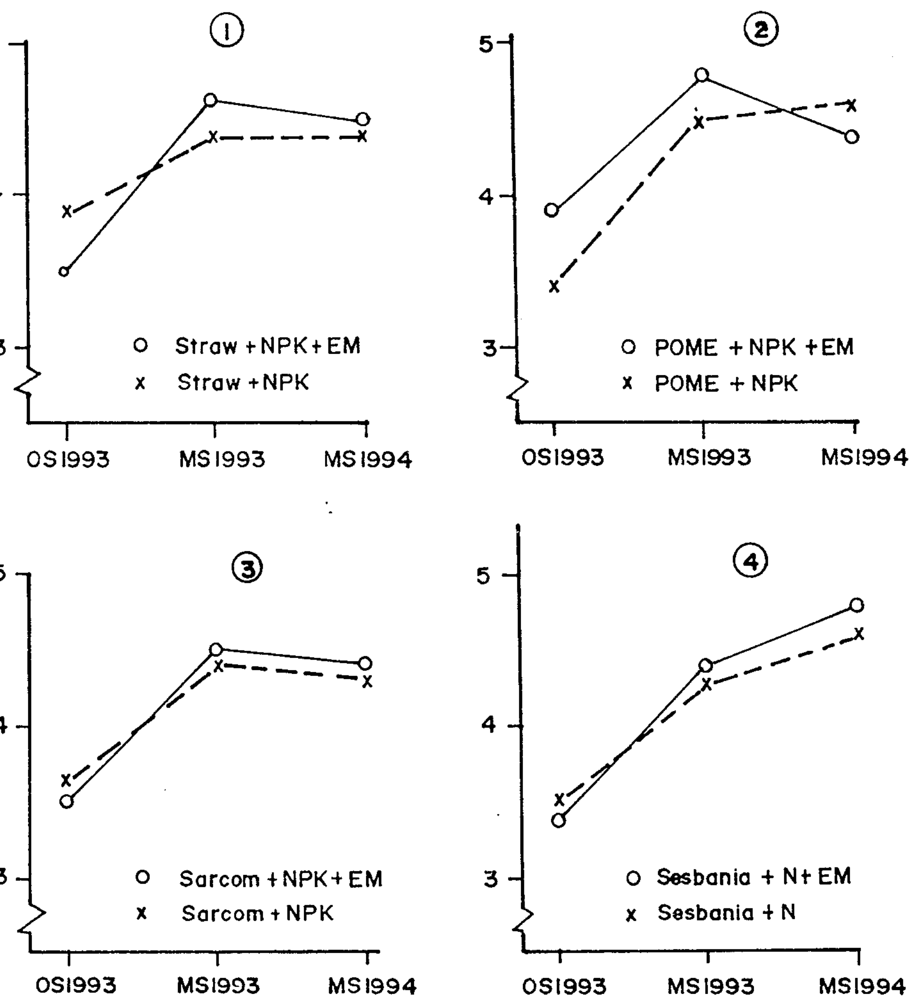

Figure 15. Rice yield with EM applied to organic matter for three seasons in MADA

yield of 8 to 22%. The good positive effect of straw may be due to the longer time allowed for the straw to decompose before it was ploughed into the soil. It was observed that with EM4 the straw decomposed faster and was easier to work into the soil. With POME there was a 5 to 8% increase in yield with a negative response of 9% during off-season 1994. The effect of EM4 on POME again has widely different responses as discussed previously.

Table 14. Effect of EM4 on grain yield of rice in PBLS

Treatment	Yield (kg/ha					
	M.S. 1993	%	O.S. 1994	%	M.S. 1994	%
Straw + NPK	3058	0	2975	0	2923	0
Straw + NPK + EM4	3310	+8	3221	+8	3555	+22
POME + NPK	3380	0	3284	0	3634	0
POME + NPK + EM4	3559	+5	2993	-9	3918	+8

The yield of rice with EM4 applied by a sprinkler system at weekly intervals in large plots is shown in Table 15. The application of NPK + EM4 gave a 9% increase in yield compared with NPK. The application of only EM4 gave a 6% decrease in yield compared with NPK. This would be considered as a good yield achievement as no NPK was used and a relatively high yield was maintained.

The field trials with EM4 in Muda and PBLS show that there is an overall increase in mean grain yield of about 10-20%.

Table 15. Effect of sprinkler applied EM4 on yield of rice in PBLS

Treatment	Yield (t/ha)	%
NPK (80:30:20 kg/ha)	4.7	0
EM4	4.4	-6
NPK + EM4	5.1	+9
Mean	4.7	
CV (%)	6.5	

7. METHANE GAS EMISSION IN RICE FIELDS

The current trend of rice productivity improvement through an integrated approach utilizing inorganic fertilizers with organic amendments is implicated to have strong influences in methane emissions. It was therefore necessary to evaluate and quantify methane emission under various management practices in the rice growing regions of Peninsular Malaysia. There has been no studies conducted or documented with regards to methane emission in Malaysia.

The increased awareness in global climate change have led to the identification of methane as one of the most important greenhouse gas. The other greenhouse gases are CO_2, N_2O, NO, possibly NO_2 and chlorofluorocarbons. The greenhouse gases have strong infrared absorption bands and trap part of the thermal radiation from the earth's surface causing elevation of the global surface temperature (Wong *et al.*, 1976; Ramanathan *et al.*, 1985; Dickinson and Cicerone, 1986).

The first evidence of an increase in atmospheric methane concentration was provided in the early part of the last decade (Graedel and McRae, 1980; Ramussen and Khalil, 1981). Since then, the atmospheric concentration of methane is reportedly increasing by about 1% per year (Fraser *et al.*, 1981; Blake and Rowland, 1988; Papen and Rennenberg, 1990). Though the atmospheric concentration of carbon dioxide is 345 ppm whilst that of methane is only 1.7 ppm, a single methane molecule traps heat about 30 times more effectively than carbon dioxide molecule. It is postulated that with the current rate of increase in atmospheric methane concentration which is faster than the increase in carbon dioxide concentration, methane will become even more devastating as a greenhouse gas than carbon dioxide. Papen and Rennenberg (1990) cite that significant methane production and emission into the atmosphere occurs only in ecosystems where anaerobic soil conditions prevail and methane emissions are exclusively caused by the activities of the strictly anaerobic methanogenic bacteria.

Flooded rice fields which account for 90% of the total rice production is the source for 25% of the 500 million tons of methane that reaches the atmosphere each year (Neue, 1991). The process of anaerobic decomposition of soil organic matter provides the required substrate for biogenic methane production. The methane gas reaches the atmosphere in three ways: (I) via the rice plant (ii) by the process of ebullition (iii) by diffusion (Figure 16). Several studies have confirmed that the rice plant is the major passage way of methane gas from soil to the atmosphere (Inubushi, 1990; IRRI, 1991; Cicerone and Shetter, 1981; Seiler *et al.*, 1984).

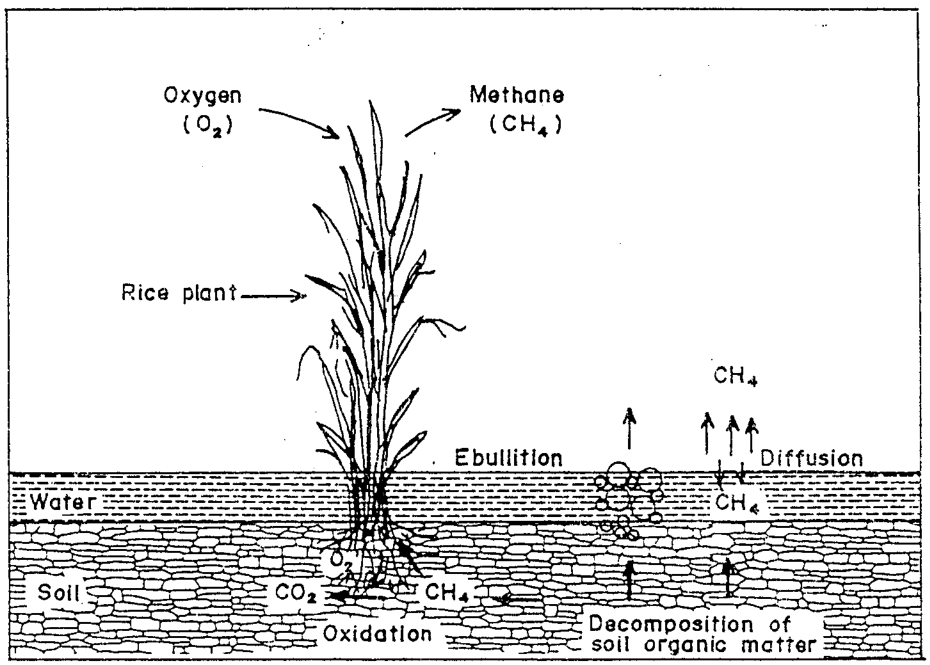

Figure 16. Process of methane emission in paddy field (IRRI 1991)

It is now well known that methane production rates depend on temperature, soil properties, management practices and there are strong seasonal variations in addition to insignification diurnal variations (Yagi *et al.*, 1990; Inubushi, K., 1990; Hori *et al.*, 1990). Turner *et al.* 1992 have expressed that it is not temperature but solar radiation and the factors associated with it that are responsible for the differences in methane emission between different growing periods.

7.1 Measurement of Methane Emission

Some commonly available organic amendments were evaluated to assess their potentials for use as an amendment to improve productivity, and measurements of methane emissions were conducted at various growth stages for the various organic materials evaluated. The organic materials evaluated were Sesbania (a green manure); palm oil mill effluent (POME); bioferti (a commercially available microbial organic fertilizer); Effective Microorganisms (EM); complehumus (a commercially available organic fertilizer); sarcom (composted rice husk); and rice straw. A control plot receiving only nitrogen, phosphorus and potassium was included (Table 5). The trial was conducted in two locations, Jerus (Pasir Putih series) in the first season (Dry season 1992) and at Perol (Chempaka series) in the second season (Wet season 1992). The trial was laid out in a randomized block design with four replications. Method of crop establishment was direct seeding. Methane emissions, soil pH and oxidation-reduction potential were determined in all the treatment plots of the first replicate at Perol. Soil pH and oxidation-reduction potential were determined at weekly intervals commencing from incorporation of the organic matter. Methane emission were determined at the following stages: (i) Before ploughing in of the organic amendments, (ii) Three days after organic amendment application, (iii) Six days after organic amendment incorporation before sowing of pregerminated seeds, (iv) At active tillering stage around 30 days after seeds broadcast, (v) Just before fertilizer application at the panicle initiation stage, (vi) At the reduction division stage 2 weeks after panicle initiation, (vii) At time of flowering, (viii) At the grain filling stage.

At each of the time period selected for determination of methane emissions, soil samples were also collected for determination of soil exchangeable ammonium nitrogen and iron (II) content.

The closed chamber method as proposed by Minami and Yagi (1988) was used for the measurements of methane flux from the soil to the atmosphere (Figure 17). The chambers were constructed from polycarbon with internal measurements of 40cm x 40cm x 90cm. The chamber was fitted with a small fan to mix the air and a pump to enable sampling of the air within the chamber. Soon after seedling establishment, areas within each treatment plot was identified corresponding to the length and breadth of the chamber and a wooden support was placed at the soil surface. At the time for methane emission measurement the chamber was carefully lowered into the water and placed onto the wooden support at the soil surface without perturbations to the soil surface. The time of placement of chamber was recorded and air samples were collected after 30 minutes and 60 minutes. The chamber temperature, air temperature and water depth were recorded at each time period. The air samples were collected in tedlar bags of volume 1200cc.

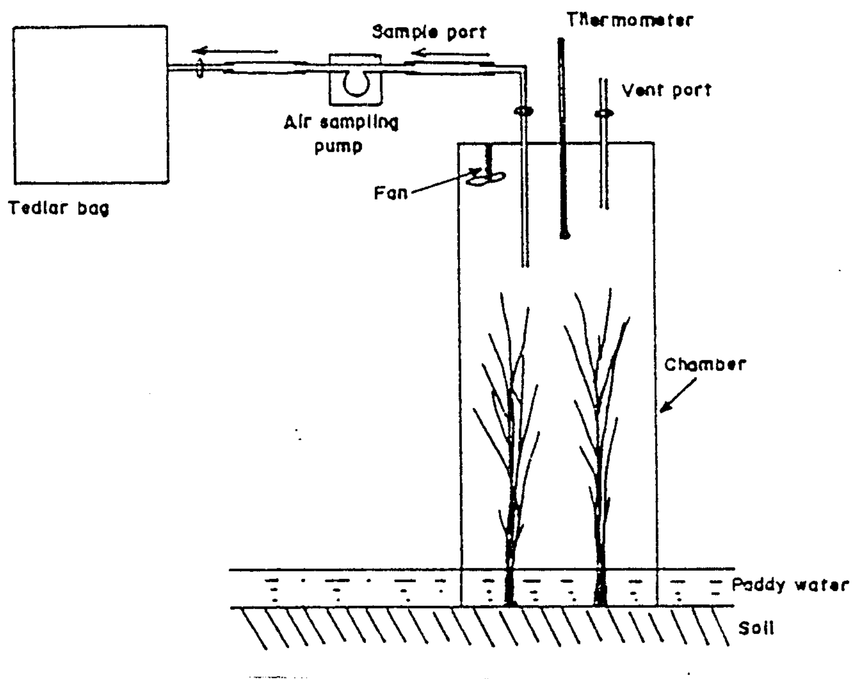

Figure 17. Schematic illustration of the chamber and the sampling system used for the measurements of the CH_4 flux from paddy field (Minami and Yagi, 1988)

Methane concentrations in the tedlar bags were determined using gas chromatograph a gas sampler and Flame Ionization Detector (FID). Prior to determination of methane in the samples, various volumes of standard methane were injected and the response by FID was used to obtain a linear regression equation (r=0.99). The linear regression equation was used to translate FID response of sample gas for calculation of methane concentration in the samples. The concentration differences between the two time intervals of 60 minutes and 30 minutes was used to calculate the methane flux.

7.2 Methane Emission

Methane emission from plots with Sesbania plants prior to incorporation was 2.35 $mg/m^2/hr$. Three days after incorporation of organic amendments, methane emission from the control plot without any amendments was almost negligible, amounting to an emission of only 0.55 $mg/m^2/hr$ and methane increased but in varying amounts with the type of organic amendment (Table 16). POME caused a high emission of methane. Methane emission was highest in the plot receiving Sesbania + POME or POME only with an emission flux of 159 and 83 $mg/m^2/hr$ respectively. Sesbania incorporated plots had an emission of 2-40 $mg/m^2/hr$. Straw incorporation after 3 days caused a methane emission of 31 $mg/m^2/hr$ but increased markedly soon after and had the highest methane emission at 6 days after incorporation with a flux of 128 $mg/m^2/hr$.

At the vegetative stage of active tillering, methane emission was low and within 20 $mg/m^2/hr$ except in plots with POME application where methane emission was about three times higher.

Table 16. Methane emissions at the various growth stages for direct seeded rice ($mg/m^2/hr$)

Treatment	-6 DAS	-3 DAS	0 DAS	30 DAS	56 DAS	74 DAS
NPK	2.35	0.55	10.49	10.51	164.80	58.56
Sesbania	n.d.	7.21	6.56	11.96	61.28	105.31
Sesbania + N	n.d.	41.87	55.31	13.51	113.29	130.40
Sesbania + POME	n.d.	158.61	15.46	61.05	82.94	924.40
POME + N	n.d.	82.72	72.64	23.91	195.61	68.82
Complehumus	n.d.	39.91	14.59	23.00	36.81	81.94
Sesbania + Bioferti + N	n.d.	2.14	4.95	4.30	48.99	58.67
Bioferti + NPK	n.d.	n.d.	n.d.	9.81	28.13	56.71
Straw + NPK	n.d.	30.82	127.87	15.47	51.22	897.61

n.d.: not determined

There was a sharp increase in methane emission at the panicle initiation stage for all treatments. Emissions were contrastingly different among treatments due to differences in growth caused by the various amendments as well as the effect of fertilizer application prior to panicle initiation. It is noted that Complehumus treated plots and those with Bioferti had markedly lower amounts of methane emission (Table 16). Plots with only POME applied reached a peak emission at the panicle initiation stage with an emission flux of 195 $mg/m^2/hr$, five times the amount emitted from complehumus plots which had the most impressive growth of rice crop at the panicle initiation stage.

The peak emission of methane for straw and POME + Sesbania plots occurred at the reduction division stage with an emission flux of 924 and 898 $mg/m^2/hr$ respectively. In contrast NPK treated plots of Bioferti + NPK had an emission of 58 $mg/m^2/hr$. It is apparent that the differences in methane emission was accentuated by the fertilizer application at the panicle initiation resulting in crop growth differences. In the trial 50% of the nitrogen fertilizer was applied at the panicle initiation stage. Nitrogen applied at the panicle initiation stage seem to have a priming effect on the decomposition process of POME + Sesbania and Straw amended plots resulting in high methane emissions.

However, methane emission from plots of a study on residual effects of POME, in the sixth consecutive crop season for transplanted rice had very low fluxes at the heading stage, ranging from 0.07 to 0.57 $mg/m^2/hr$. Similarly methane emissions determined for transplanted rice under various organic amendments in PBLS at 50 days after transplanting had relatively lower methane emission fluxes (Table 17). In rice planting with conventional fertilizer application the methane gas emission was 14.28 $mg/m^2/hr$. The incorporation of organic matter into the soil in the form of green manure or other sources increases the reduced condition of the soil and enhances methane gas emission to 26.08 $mg/m^2/hr$.

The correlation between oxidation-reduction potential of the soil and methane emission at the various growth stages was low and insignificant ($r = -0.19$) for direct seeded rice in the KADA region. A higher positive insignificant correlation ($r = 0.47$) occurred for the transplanted rice situation in PBLS. The higher magnitude is attributed to a very small sample size of five. Similarly oxidation-reduction potential and Iron (II) content and exchangeable ammonium nitrogen and methane emission had a poor correlation of r = 0.19 and r = -0.24 respectively. However methane emissions and Iron (II) contents had significant positive correlation, r = 0.46** (Xaviar, *et al.*, 1995).

Table 17. Methane gas emission in PBLS

Treatment	pH	Eh (mV)	Methane emission ($mg/m^2/hr$)
NPK	6.43	-181	14.28
Sesbania	6.48	-260	26.08
POME	6.38	-208	16.77
Sesbania + POME	6.42	-254	20.57
Complehumus	6.40	-192	15.14

7.3 Daily Trend in Methane Emission

The field studies were carried out in PBLS on marine alluvial soils. The treatments consisted of (i) NPK (ii) Straw + NPK and (iii) Sesbania + NPK. The NPK was applied at 80 kg N/ha, 30 kg P_2O_5/ha and 20 kg K_2O/ha. The straw and Sesbania treatments were 5 t/ha. The plot size was 5m x 5m and randomized block design was used with 8 replications.

Gas samples were taken at three hour intervals from 7 am in the morning to 7 pm in the evening. As there were a large number of samplings with 8 replications the work had to carried out over 4 days by sampling 2 replicates each day. A statistical analyses was carried out on the methane flux over the various times of the day at the various growth stages.

At the panicle initiation stage sampling was carried out in only 4 replications and the statistical analysis on the methane flux and time are given in Table 18.

The methane flux with time was close to the 5% level of significance. The graph of methane emission over time (Figure 18) showed an increase in methane flux from 7 am to attain a peak at about 1 pm to 3 pm and then to decline in the evening at 7 pm. The curve corresponded with the soil temperature which was 26°C at 7 am and increased to 30°C at 1 pm and then declined again to 27°C in the evening (Samy, *et al.*, 1994).

Table 18. Statistical analysis of methane flux at panicle initiation stage

Source	Df	Type III SS	F-value	PR > F
Replicate	3	813.79251415	2.41	0.1100
Time	1	500.89111369	4.46	0.0532
$Time^2$	1	406.85337945	3.62	0.0778

CV = 37.6929%
Model R^2 = 0.47097

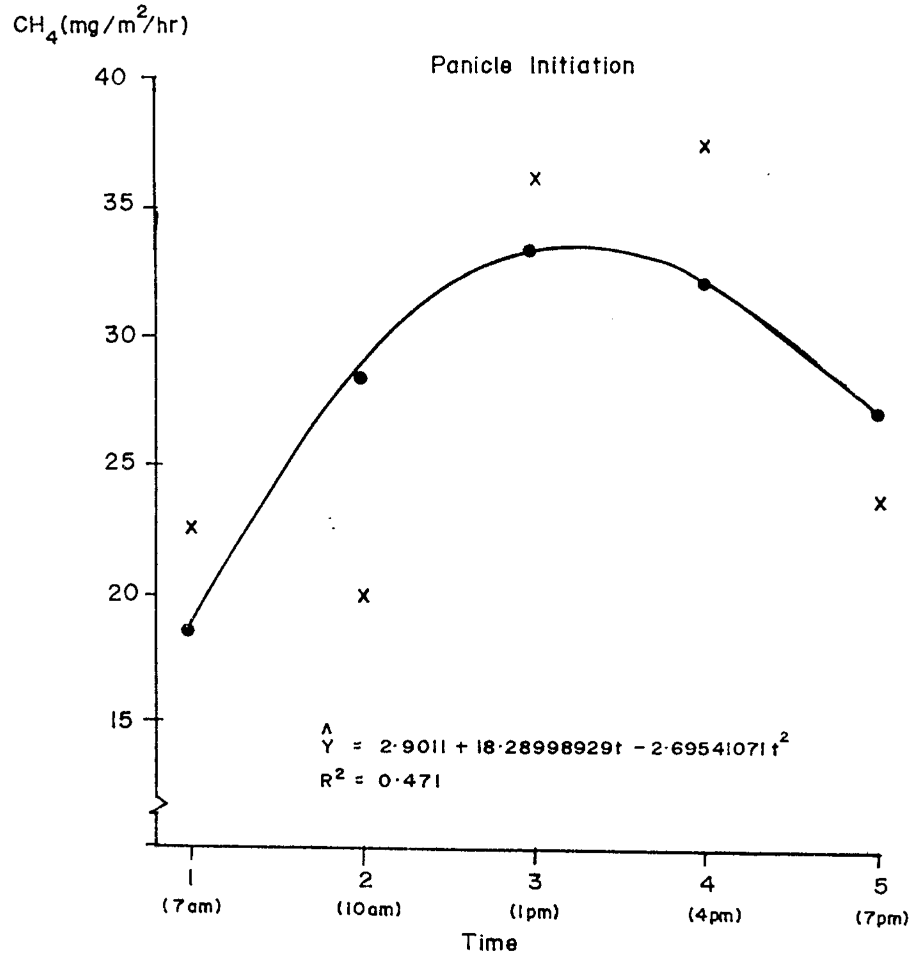

Figure 18: Methane emission at panicle initiation stage

In the statistical analyses on methane flux in the other treatments it was not possible to detect an acceptable level of significance for 'time' and $(time)^2$. This was because of the wide variation in the results within the treatments. However, the observed mean values showed a similar trend. For example in the field treatment of straw + NPK at the heading stage there was peak methane emission at 1 pm, and for the treatment Sesbania + N at the heading stage there was a peak at 4 pm.

It can be concluded that there is a peak methane emission during the daytime at around 1 pm to 4 pm. This period corresponds with the peak soil temperature during the day.

7.4 Effect of Effective Microorganisms (EM) in Methane Emission

The effect of various organic matter and EM on methane at various stages of rice crop in Muda is given in Table 19. It is evident that the application of EM with the various types of organic matter: *S. rostrata*, Sarcom and POME generally resulted in a reduction in the emission of methane at the various growth stages, except at ripening stage. EM was not applied during the grain formation stage and the last application was before flowering. Figure 19 shows the mean reduction in methane emission with the application of EM with *S. rostrata* was 54%, with Sarcom there was a 43% reduction and with POME a 19% reduction. In the treatment with 5 t/ha of straw incorporation however the application of EM gave a 94% increase in methane emission (Samy, *et al.*, 1995).

Straw has a very high C/N ratio of 80, and the very high level of straw at 5 t/ha incorporated in the soil could have influenced the high methane emission. In contrast, the

C/N ratio of the other organic matter treatments were very much lower, with *S. rostrata* at 4.79-6.18, POME at 5.6 and Sarcom at 40.

Table 19. Effect of EM4 on methane emission at various stages of rice crop in Muda

Treatments	Maximum tillering	Reduction division	Heading stage	Dough stage	Ripening stage	Mean	%
			(mg/m^2/hr)				
S. rostrata + N	368	18	26	23	17	90	0
S. rostrata + N + EM4	137	10	26	13	24	42	-54
Sarcom + NPK	191	16	26	7	5	49	0
Sarcom + NPK + EM4	85	15	8	13	19	28	-43
POME + NPK	475	18	22	17	4	107	0
POME + NPK + EM4	375	24	9	13	15	87	-19
Straw + NPK	202	19	16	16	9	52	0
Straw + NPK + EM4	385	25	19	43	26	102	+94

Rates: S. rostrata seeding at 50 kg/ha, Sarcom: 5 t/ha, POME: 5 t/ha, Straw: 5 t/ha, NPK at 80:30:20 kg/ha.

The results of the field trial in PBLS are given in Table 20. It was observed that NPK + EM treatment consistently gave a reduction in methane emission compared with NPK at the tillering and panicle initiation stages, with a mean reduction of 46% (Figure 20) and POME + NPK + EM also gave a mean reduction in methane emission of 9%. It was again evident that the incorporation of 5 t/ha of straw enhanced the methane emission particularly at the tillering stage, but at the panicle initiation stage there was a small

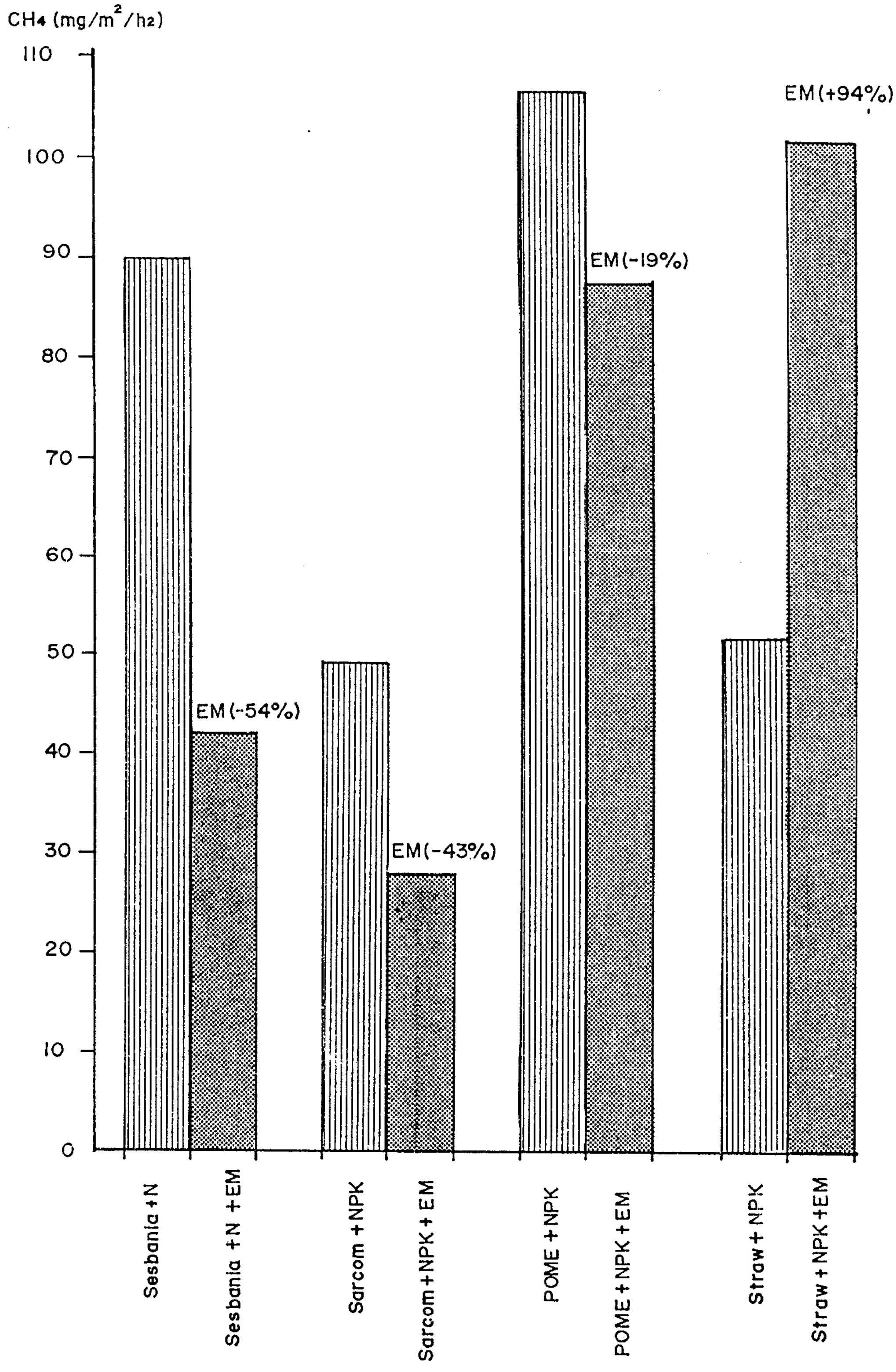

Figure 19. Emission of methane with the application of organic matter and EM in Muda

decline. In the NPK + EM treatment where only the straw stubble of the previous crop was ploughed into the soil there was a decline in methane emission.

Table 20. Effect of EM4 on methane emission in PBLS

Treatments	Tillering stage	Panicle initiation	Mean	%
		($mg/m^2/hr$)		
NPK	36	41	39	0
NPK + EM4	22	19	21	-46
POME + NPK	40	22	32	0
POME + NPK + EM4	41	17	29	-9
Straw + NPK	43	28	22	0
Straw + NPK + EM4	63	22	42	+90

Rates: NPK at 80:30:20 kg/ha, POME: 5 t/ha, Straw: 5 t/ha

Effective microorganisms can decrease the emission of methane because of the processes involved in the decomposition of organic matter. The photosynthetic bacteria in EM performs incomplete photosynthesis by using heat or sunlight energy, separating and utilizing hydrogen in intermediate products, such as methane gas, indole, skatole, methyl captan, and various organic acids which are produced in the process of decomposing organic substances (Higa, 1988).

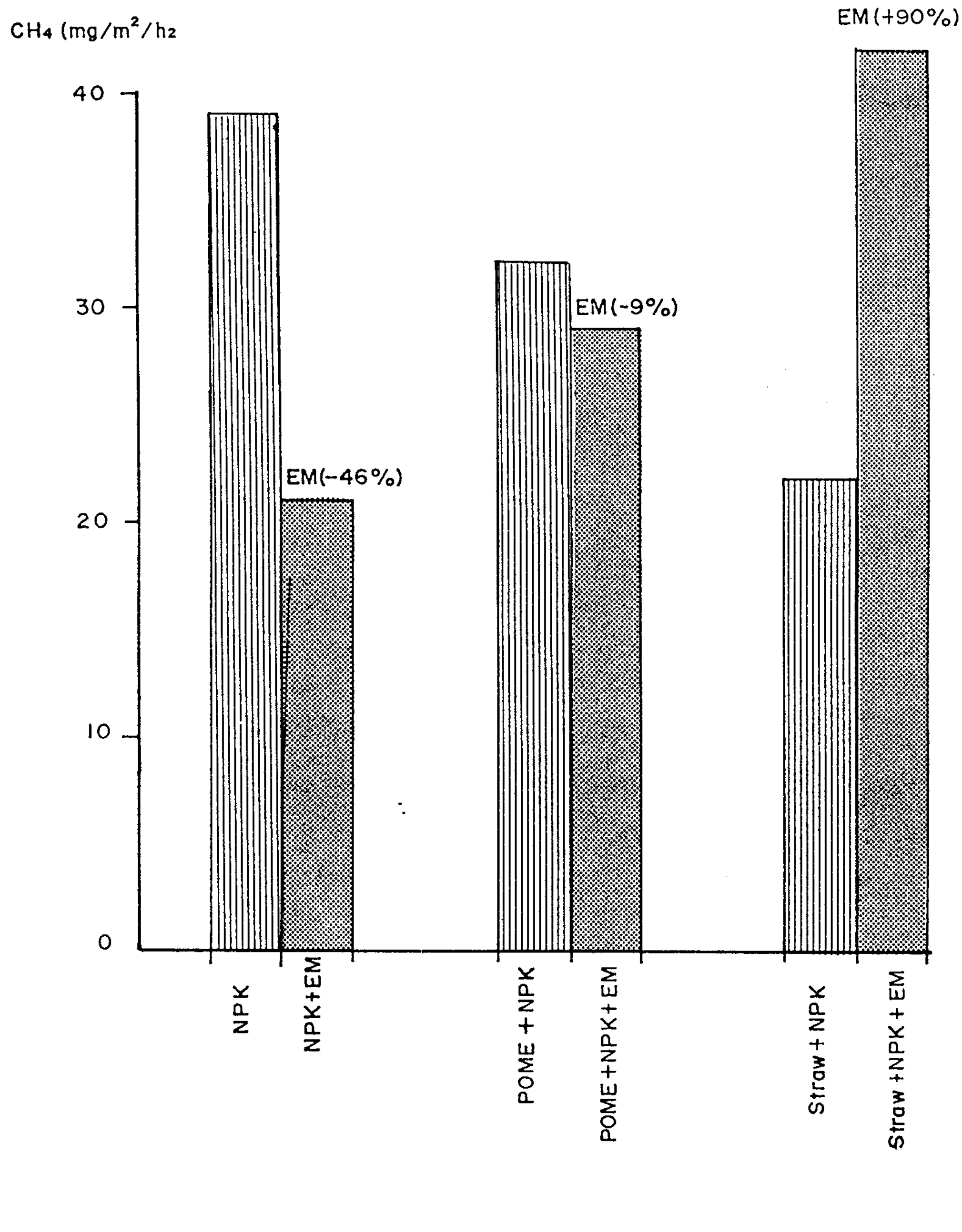

Figure 20. Emission of methane with the application of organic matter and EM in PBLS

7.5 Inventory of Methane Gas Emission

The three rice granaries where methane emission studies were carried out account for about 46% of the total rice area of Malaysia and with the different soil types and planting methods it would give a good representation of the mean methane emission level in Malaysia. The methane gas emission inventory for the rice areas of Malaysia has been calculated and given in Table 21.

Table 21. Inventory of methane gas emission from flooded rice in Malaysia

Location	Cropping method	Physical area (ha)	Methane gas emission (Tg/hr)
Peninsular Malaysia	Double cropping	212,497	0.44
	Single cropping	28,441	0.0295
Sarawak	Single cropping	76,200	0.079
Sabah	Single cropping	32,000	0.033
Total		349,138	0.5815

The total methane emission from flooded rice in Malaysia is 0.5815 Tg/hr, and the contribution of Malaysia to the global flooded rice methane emission is 0.94% (Samy, *et al.*, 1994). This relatively low figure is attributed to the small rice area, and Malaysia can be considered as not being a major contributor to methane gas emission gas emission from flooded rice.

8. CONCLUSION

The continual usage of NPK fertilizers in rice over the past 25 years have caused nutrient imbalances non-conducive to high yields. This is due to an excess or insufficiency of specific macro and micro nutrients or organic matter status of soil. An Expert System of Nutrient Management for rice taking into consideration the various soil and environmental parameters was developed, and it showed that rice yields can be enhanced by 15-62%. A complete computer programme on the Expert System has been prepared to directly derive precise fertilizer recommendations for any rice area of the country, and this has been submitted to MARDI.

The incorporation of organic matter in rice soil causes the oxidation-reduction potential to fluctuate with growth of the rice crop and is lowest at about maximum tillering stage with a minimum of –230mV. There were only slight differences in pH of 0-5 units throughout the growth of the rice crop. There was a general increase in ferrous iron content with the use of organic matter but no visual symptoms of iron toxicity was observed. The use of organic matter in flooded rice soil has environmental problem as it enhances the emission greenhouse gas methane.

The studies show there is good potential for organic based rice farming with a combination of organic and inorganic fertilizers to attain maximum yields. It is possible to plant rice by organic farming without any chemical fertilizers by maintaining a high organic matter status of soil to obtain high yields, as shown in the case of POME or a combination of various organic matter sources. However, the amount of organic matter required regularly is very high in the range of 15-20 t/ha. Effective microorganisms play an important positive role in the management of organic matter in rice field and to minimize the emission of methane.

9. ACKNOWLEDGMENT

The authors are most grateful to the Developing Countries of the Group of 77 for Economic and Technical Cooperation, for providing the research grant from the Perez-Guerrero Trust Fund (PGTF) to undertake the studies on organic rice farming system. Thanks are also due to the former Director General of MARDI, Tan Sri Dr Mohd Yusof bin Hashim and the present Director General Datuk Dr Md Sharif bin Ahmad for facilitating the research grant and their keen interest on the progress of the studies. Special thanks are accorded to the past Directors of the Fundamental Research Division, Dr Ahmad bin Zam Zam and Dr Aminuddin bin Yusoff, and presently the Director of Strategic, Environment and Natural Resources Research Centre, Tuan Hj Embi bin Yusof for their continual support in the research on organic farming. Our sincere thanks to the Research Assistants in MARDI office, MADA, KADA, Tanjung Karang and Serdang for carrying out the field trials very diligently. Last but not least our special gratitude to Encik Che Leman bin Hamzah and Encik Ab Rahim bin Jais for helping in the final preparation of the report.

Date: 12 June, 1997.

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