Soil fertility implications for organic rice production in the Lao PDR

Roder, W., S. Schürmann, P. Chittanavanh, K. Sipaseuth, and M. Fernandez

Abstract

Rice is the most important agricultural commodity of the Lao PDR, produced largely using traditional methods with limited inputs of fertilizers and other chemicals. The country has a wide diversity in rice production systems and rice varieties, with over 3,000 different varieties recorded. The conditions are considered to be favorable for organic rice production. Investigations were carried out to describe soil fertility conditions, management practices, opportunities and problems in connection with organic production methods.

Soils used for rice production are mostly of low fertility, with low organic matter and N-availability being major constraints. In spite of this, virtually no fertilizer inputs are used for upland rice production. Fertilizer input for lowland rice production have increased fast over the last decade, but are still below 20 kg/ha. The most important nutrient sources are rice straw and manure from buffalo and cattle. Chromolaena odorata, plays an important role in nutrient cycling in upland rice system and is sometimes added to lowland fields.

Yield increase across a range of locations and years ranged from 2-89% for manure, straw or rice husked applied at modest rates, 32-156% for modest rates of inorganic fertilizer and 36-167 % for combined application of manure or crop residues with inorganic fertilizer. The response to locally produced commercial organic fertilizer was poor.

The most promising inputs and strategies available to optimize yields in organic rice production systems are 1) the locally available nutrients, mostly from manure, crop residues and weed biomass, 2) N addition through green manure and legumes growing in rotation and 3) additions of P through guano or rock phosphate. The Lao PDR is fortunate to

Introduction.

Rice is by far the most important crop for the Lao PDR, planted on more than 700'000 ha annually. Based on water management the rice growing area is grouped into rainfed lowland, irrigated lowland and upland rice each of these are representing approximately 75, 11 and 14
% the total area under rice (National Statistics Centre, 2005). Rice yields are generally low
with a national average of 3.4, 4.4 and 1.8 t/ha for rainfed lowland, irrigated lowland and
upland, respectively. Most of the rice varieties are glutinous. Lao rice producer generally
consider the absence of a market or the low market price as the main factor limiting
unpublished). At the same time the production of speciality rice and/or organic rice for
export markets is often seen as a promising opportunity for Lao rice farmers (FAO, 2001;
Sipaseuth et al. 2004). In the last few years the interest for organic production and
expectations from market opportunities for organic products from the Lao PDR have
increased fast (Chittanavanh et al. 2005). The Ministry of Agriculture and Forestry and
various projects and organisations are promoting organic production methods for market
production and for home consumption. Prevailing conditions favouring organic rice
production generally listed include: 1) Many rainfed rice production environments are
marginal with limited response to high yielding varieties and high input systems, 2) Lao rice
producers presently use only limited fertilizer inputs and 3) traditional production methods
still widely used are largely organic (Helvetas, 2005. ProRice - Phase I, 2006-2008. Project

In the European or North American context, organic agriculture with annual crops is mostly
based on mixed farming systems with legumes in the rotation and high inputs of manure.
Under European conditions cereal grain yields from organic production systems are about 10-
30% lower when compared to conventional systems. Furthermore, studies comparing organic
and conventional production have generally used same rates of N provided either through
manure or compost for organic treatments and through in-organic fertilizers with or without
manure for conventional treatments (Raupp 2001; Mäder et al. 2002). With N application
rates of 100 kg and above, the manure application for organic treatments are in the range of
10-20 t/ha.

Soil fertility management will be a major challenge for organic rice production in the Lao-
PDR. The European and North American experiences will have limited application as the
Lao rice farmer will not have the benefits of a mixed farming system nor will he have access
to the required quantities of manure. Fortunately, substantial information on soil fertility
management, the use of organic fertilizers, residue management and green manure has been
generated under Lao conditions, some of these results and experiences can be directly applied for organic production. Investigations were carried out with the objectives to:

1. describe current soil fertility conditions and management practices for the major Lao rice production systems
2. summarize experimental soil fertility management data relevant for organic rice production in Laos
3. describe inputs available and recommendations given for soil fertility management in organic production systems

Methods

Literature review, secondary data
Documents and information relating to fertility management in general and the use of organic inputs in particular, were collected from published and unpublished documents and reports.

Survey rice producers
An economic survey was carried out in 2004 in 3 districts of Champasak province with the objective to analyze economic data (Schürman, Stefan. 2005, unpublished. Agriculture Production Economics in Laos: A data analysis of the Champasak Province and a data processing concept for agriculture extension. Diploma Thesis). Formal survey questionnaires were used to collect production and economic data. The results for cost of inputs and rice yields were used in this paper.

Studies by LAO-IRRI project and others
From 1990-2002 the Lao-IRRI project carried out a range of studies evaluating the effect of organic fertilizer, manure, rock phosphate, straw applications and green manure in lowland and upland rice production systems across a range of environments (Lao IRRI, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004). The results available in annual reports were revisited and results summarised. Findings generated by an FAO project (FAO, 2004) were also included in the discussion.

Survey organizations recommending organic agriculture
Information was collected from Non-government organizations recommending organic agriculture or clean agriculture through informal interviews supported by questionnaires.

Locally available source of inputs
Information was collected on existing and potential locally available source for soil fertility management in organic agriculture through literature and visits to input suppliers, and fertilizer factories.

Results

Soil fertility and current management practices for lowland rice
Lowland rice soils in the southern part of Laos are predominantly Acrisols (Linquist and Sengxua, 2001). Typically these soils are highly weathered, have a low inherent fertility, a low pH and a low cation exchange capacity. Soil data (0-20cm) indicates that 80% of the soils in the south contain less than 2% organic matter, 68% are coarse textured sand and 87% have a pH of less than 5.5. Of all elements tested, N was the most important yield limiting factor but the severity varied considerably between sites (Linquist and Sengxua, 2001). P was the second most limiting factor with 71% of the sites in the south and 37% of the sites in the north responding to P application. In spite of the low fertility, using chemical fertilizer for rainfed lowland rice production is a recent introduced practice for Laos. In a survey conducted in 1996, 60% of the farmers reported that they started using fertilizer in 1995 only (Pandey and Sanamongkhoun, 1998). In the last 10 years fertilizer consumption has increased rapidly. In the survey in 2 districts of Champasak Province only 3 house holds out of 196 house holds included used no fertilizer for rainfed rice production. There was a strong relationship between investment in fertilizer and rice yield (Figure 1), but the data also shows that there was little return for investments in fertilizer above USD 20/ha. Rice producers are generally not optimizing the benefits from manure and crop residues. Straw removed at harvest is often burned after threshing or used as livestock feed and limited efforts are made to increase the quantity or quality of manure produced.

Soil fertility and current management practices in upland rice
Upland soils are generally poor, mainly red-yellow, podzolic, and reddish brown lateritic, leached and acidic, with low water-holding capacity (Roder, 2001) and soil fertility is generally cited as a major constraint in upland rice production. Yet, extensive investigations
focusing on soil-related factors that may affect rice yield failed to show a conclusive relationship between conventional soil fertility parameters and rice yield and fertilizer applications did not show consistent results (Table 1, Roder, 2001). In spite of the inconsistent response, N is clearly limiting rice yields. N-stress is especially likely to affect yield during the later part of the growing season as indicated by a strong relationship between leaf chlorophyll at the time of flowering and yield (Roder, 2001). Application of P resulted in increased P uptake of 38% but had no consistent effect on grain yield (George et al. 2001). Upland rice producers are presently not applying any fertilizer or manure. With a gradual decline in the level of organic matter because of shorter fallow cycles, it is expected that N stress may become more accentuated. For sustained upland rice production it will be important to limit N and organic matter losses through soil conservation, especially by practices that emphasize residue management and to provide sufficient N during the critical stages of the rice crop through N-rich residues of forages/crops grown in rotation and/or appropriate fertilizers.

Various studies focused on the effect of residue management on rice yield, weed biomass, and other parameters (Fahrney, 1999; Roder, 2001; Roder et al. 1998a). Although drought is considered a major yield constraint, no positive short-term benefits of mulching for grain yield could be demonstrated except in a study involving mulching with pigeonpea (*Cajanus cajan*) residues (Table 4). Burning of crop and fallow vegetation residues consistently reduced weed biomass and made field preparation easier.

**Nutrient sources**

Lao rice producers mostly rely on the production capacity of their soils. Until recently limited quantities of nutrients were added through manure or in-organic fertilizers and before 1980 the quantities of chemical fertilizers imported were negligible (FAO, 2005; Figure 2). Based on the FAO statistics the average fertilizer consumption is <10 kg/ha land cultivated. The most important nutrient sources for organic rice production will be manure, crop residues and compost made from materials available at village level. Most of these nutrients are already used, but there are opportunities to improve the utilization and reduce losses, especially for nitrogen. The weed, *Chromolaena odorata* plays a special role in nutrient cycling, especially in upland environments (Roder et al. 2006). Occasionally biomass of this species is also used by lowland rice producers.
Cattle and buffalo are important sources of plant nutrients and agents in accelerating nutrient cycling. To some extend they also serve as vehicle transferring nutrients from fallow land and forest to the rice fields. The available statistics indicate that there are 1.8 head cattle and 1.6 buffalo per ha of rice. Lowland rice farmers are more likely to have buffalo, while upland rice farmers are more likely to have cattle. Traditionally buffalo are used for field preparation in lowland systems.

Lowland rice farmers are however gradually replacing buffalo with tractors and there is a tendency of decreasing livestock numbers (Figure 3). Consumer sources of nutrients which are permitted for organic agriculture are bio-fertilizers, bat guano and rock phosphate.

Addition of micro-organisms to hasten decomposition of organic matter is widely recommended for compost making ( ), especially a technology known as EM (effective micro-organism). This technology may accelerate nutrient cycling and availability but it does not bring additional nutrients to a system.

**Bio-fertilizers:** In the late nineties the Government of Lao PDR has established 10 bio-fertilizer factories, with a production potential of 88400 t/year (FAO, 2004). In the year 2004 these factories produced about 20’000t. All factories use similar raw material with peat (60-80%) from a lake being the main ingredient. A range of other products are added and composted together with the peat such as slaughterhouse by-products, by-products from beer, sugar, and tobacco processing, rock phosphate and guano (Personal communications, manager Dongxiengdy factory, Vientiane, 2005). All components are mixed, a solution of micro-organisms is sprayed on and then the mixture is fermented for 20-30 days. Analytical data are available for 5 factories (Table 2). Because of limited crop response, farmers have shown little interest and five factories have stopped production in 2005 due to limited market. Furthermore, following the IFOAM standards fertilizers with peat basis would be allowed for potted plants only.

**Rock phosphate and guano:** According to some reports the guano deposits in Laos are quite substantial. Rock phosphate is found in Khammuane Province. Rock phosphate and guano deposits have been documented by the Department of Mineralogy. It is quite likely that the deposits referred to as “rock phosphate” are actually mineralized guano (Roder, W. P. Chittanavanh, K. Sipaseuth, and M. Fernandez, 2005. Inputs available for organic farming,
The P and N content of the guano deposits vary (Table 3). The content is largely depended on the age and the stage of mineralization.

Experiences with inputs permitted in organic agriculture

Effects of manure and crop residues for lowland rice: The Lao-IRRI project has evaluated effects of manure, straw or rice husk over a wide range of environments (Tables 5-7, Lao-IRRI, 1998, 1999, 2000, 2001, 2002, 2003, 2004). These studies showed that manure, straw or rice husked applied at modest rates can increase yields by 10-80%, while modest rates of inorganic fertilizer applied alone can increase yields by 30-150%. In all experiments the yield increase was consistently higher with in-organic fertilizers and highest when in-organic fertilizer was combined with manure application. The residual effect of repeated manure applications was not apparent. In these studies, the nutrient quantities applied through manure or crop residues were, however, always below the nutrient quantities applied through in-organic fertilizers.

Current soil fertility management recommendations of the government extension system emphasize the benefits from using straw and rice husk. Rice farmers are, however, often reluctant to follow these recommendations. Farmers limited interest in utilizing straw and manure are influenced by the difficulties faced in collecting and transporting manure or straw and difficulties in field preparation when using straw. Furthermore, crop yellowing is often observed during the first week following transplanting when straw is incorporated due to N immobilization.

Commercially organic fertilizers and rock phosphate: Data is available from studies with commercially available bio-fertilizer across a wide range of locations (Table 6). One of these studies was repeated over up to 4 seasons. The response to the bio-fertilizer is, generally poor. A recent FAO project for the promotion of organic fertilizers tested the bio-fertilizer across a wide range of rice production environments with application rates of 600 kg/ha but could not see any response in yield (FAO, 2004). Based on this study it was concluded that the nutrient content of the bio-fertilizers leading to the need of high application rates, thus making the fertilizer too expensive.

The results of the limited studies with rockphosphate (imported from Kunming) are very promising (Table 7). The response to rock phosphate was generally better than to triple
superphosphate. The locally available guano deposits provide another source of phosphate with high P concentrations (Table 6). Yet, no results of field studies using this excellent P fertilizer are available from Laos.

**Experiences with green manure species**

Green manure species have been widely tested and recommended for all rice growing environments (Roder, 2001, Lao IRRI, 1997). In spite of this none of the species/systems recommended have been adopted on a wider scale. Both, lowland and upland rice farmers are sometimes using grain legumes in rotation with rice, especially vigna species and peanuts.

**Lowland rice environments**

Green manure species tested included Aeschynomene afraspera, Crotalaria juncea, Sesbania aculeate, Sesbania rostrata, Vigna radiate, Vigna unguiculata, Black bean (Lao-IRRI, 1997). Based on studies repeated over location and years it was found that Crotalaria juncea, and, Vigna radiate are unsuitable for periodic saturated soil conditions that are an usual feature in rainfed lowland environment. Sesbania rostrata was promising but it could not be recommend because it is a host of the root-knot nematode (Meloidogyen graminicola). In order to have optimum N-fixation, green manure legumes generally require higher P-levels than rice. In a study across 3 location the dry matter production of S. rostrata was 0.6, 2.4 and 2.9 t/ha with 0, 30 and 60 kg P/ha, respectively (Lao-IRRI, 1996). Phosphorus is likely to be a major limitation for using green manure in some lowland rice growing environments.

**Upland rice environments**

A wide range of legumes have been tested for fallow and/or soil fertility management in upland rice production systems. Already in 1930, Goubeaux worked with 46 legume species. The presence of Mimosa invisa, a serious weed in some isolated upland areas, is an unpleasant testimony of those activities. The main species promoted by various agencies for fallow improvement over the past two decades were Leucaena leucocephala, Gliricidia sepium, pigeonpea, and Calliandra calothyrsus. In addition the following species were recommended based on work carried out by the Lao-IRRI project: Arachis pintoi, Calopogonium caeruleum, Centrosema pubescens, Crotalaria anagyrvides, Lablab purpureus, Leucaena diversifolia, Stylosanthes guianensis, Pueraria phaseoloides, and
Mucuna cochinchinesnis (Roder, 2001). Most of the species evaluated have multiple uses including food, fodder, and/or fuel. Pigeonpea received special attention with activities focusing on: collection and testing of local and introduced cultivars, establishment methods, rotation effects, residue management and weed suppression (Roder et al. 1998b). Important findings from studies carried out between 1991-1999, over a range of locations include:

- Replacing fallow vegetation through legumes had generally no effect on rice yield and weed biomass (Roder, 2001);
- Interplanting rice with shrubby perennial legumes (pigeon pea, L. leucocephala, C. anagyrondes) can add to total biomass produced and suppress weeds during the dry season fallow (Fahrney, 1999)
- *Arachis pintoi* is not suitable for live mulch systems due to competition for moisture (Roder et al, 1995).
- Pigeon pea, C. anagyrondes and S. guianensis are the most promising legume species for upland rice systems (Roder, 2001).
- Residue management is a critical issue and for most species tested field preparation without burning was difficult (Roder and Maniphone, 1998)
- Intercropping with L. leucocephala reduced rice yield in dry years (Fahrney, 1999)
- Most legume species can be easily established by broad casting seed immediately after the last rice weeding or by mixing seed with rice seed and dibbling together. The latter can, however, affect rice yield negatively (Roder and Maniphone, 1995).

The adoption of fallow management strategies and fallow species will depend largely on the farming systems evolving. Pigeonpea for example, is a very promising species but only if the seeds have a market or if the plant is used in a cut-and-carry system for ruminants or pigs. *L. leucocephala* has potential in a system that may still involve the use of fire and/or if firewood has a certain market value.

**Recommendations given for soil fertility management**

Of all the organizations/projects visited only two are promoting “organic agriculture” as per international definitions (Table 8). All other projects/organizations are promoting “chemical free agriculture”. The main recommendation given to the producer is “stop using chemicals”. Some organizations have no recommendation for soil fertility and pest management. Others recommend the use of compost. Bio-extract (BE), Effective
microorganisms (EM) and Bio control are the only other recommendations given. Surprisingly none of the organizations are promoting the use of green manure. Except for EM, no information was found documenting systematic evaluation of the recommendations under Lao conditions. Similarly, no reliable information is available on the adoption rate for any of the recommended technology. The limited availability of plant nutrients or sources of organic fertilizers (especially cow dung) was, however, recognized by two organisation as the main problem.

**Implications for organic rice production**

Lao farmers are producing rice under marginal conditions with low yields and low yield potentials. This is often considered as an advantage for organic production as response to inorganic fertilizers is limited. Yet, soil fertility will be the most important constraint for organic rice production. In order for rice producers to benefit from organic production, practical, effective and economic soil management strategies have to be available. Strategies and recommendations need to be based on local soil conditions, existing management practices and locally available nutrient sources. Unlike in Europe or Northern America the farmers have to develop soil fertility management strategies without having the options of a traditional mixed cropping system with legumes or a system with large volumes of organic manure available. Depending on the evolving production system it may be necessary to import certain inputs, especially phosphates.

The most promising technologies available to optimize yields in organic systems include:

- Optimise the use of locally available nutrients, mostly from manure, crop residues and weed biomass
- Add N to the system through green manure and legumes growing in rotation
- Add P through guano or rock phosphate

Through optimal management of these nutrient sources it will be possible to maintain or even improve present rice yields in most situations. Producers may require support in the supply of inputs (seed green manure species, guano, rockphosphate), marketing of new products (pulses grown in rotation, livestock products) and the development of appropriate management strategies.
Research, advisory services and other agencies making recommendations to producer need to be keenly aware that:

- Constant efforts have to be made to minimize confusion about the meaning of “organic agriculture”. Till recently most agriculture in Lao PDR was organic, yet the idea of “organic agriculture is introduced as a “new concept” with a wide range of different interpretations. This has resulted in tremendous confusion and misunderstandings.
- The principles of soil fertility management are the same for organic and conventional systems. Plants do remove nutrients from the soil, which have to be replaced.
- When developing/recommending soil fertility management strategies it will be important to always be cautious about additional labour or investments.

References


Figure 1. Investment in fertilizer and rice yield for rainfed rice in Kong, Sukumma and Phonethong district (Champasak Province) Source: Schürmann, 2005
Figure 2. Fertilizer import (each bar represents average of the year indicated and the year before). Source: FAO, 2005.

Figure 3: Buffalo density (nos/ha lowland rice) given for the national level and two major rice producing provinces Saravanne and Champasak (Source: National Statistics centre (2005))
Table 1. Results of fertilizer studies in upland rice

<table>
<thead>
<tr>
<th>Parameters studied</th>
<th>Effect on rice yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application of N during early phase</td>
<td>0–20</td>
</tr>
<tr>
<td>Application of N during booting stage</td>
<td>0–40</td>
</tr>
<tr>
<td>Application of N after flowering</td>
<td>0–70</td>
</tr>
<tr>
<td>Application of N in 2 splits</td>
<td>0–69</td>
</tr>
<tr>
<td>Application of N in 3 splits</td>
<td>0–80</td>
</tr>
<tr>
<td>Application of P fertilizer</td>
<td>0–15</td>
</tr>
</tbody>
</table>

Source: adapted from Roder 2001

Table 2. Nutrient composition of Bio-fertilizers

<table>
<thead>
<tr>
<th>Factories</th>
<th>Composition of plant nutrients (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
</tr>
<tr>
<td>Dong xiengdy</td>
<td>1.5</td>
</tr>
<tr>
<td>Xiengda</td>
<td>2.8</td>
</tr>
<tr>
<td>Maliny</td>
<td>1.5</td>
</tr>
<tr>
<td>Savannakhet</td>
<td>3</td>
</tr>
<tr>
<td>Champasack-46</td>
<td>1.5</td>
</tr>
</tbody>
</table>

Source: FAO, 2004

Table 3: Nitrogen and phosphorus content of guano samples

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>0.12</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>3.6</td>
</tr>
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</table>

Table 4. Effect of residue management and mulching in upland rice

<table>
<thead>
<tr>
<th>Parameters studied</th>
<th>Effect on rice yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mulching with rice straw</td>
<td>Reduction 0-50</td>
</tr>
<tr>
<td>Mulching of pigeonpea residue</td>
<td>Increase 57</td>
</tr>
<tr>
<td>Mulching with C. odorata (fresh)</td>
<td>0</td>
</tr>
</tbody>
</table>

Source: Roder, 2001
Table 5 Effect of manure, rice straw, and rice husk on rice yields

<table>
<thead>
<tr>
<th>Year/season</th>
<th>Fertilizer (t/ha)</th>
<th>Yield (t/ha)</th>
<th>Yield increase (%)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N&lt;sup&gt;1&lt;/sup&gt;</td>
<td>M&lt;sup&gt;2&lt;/sup&gt;</td>
<td>S&lt;sup&gt;3&lt;/sup&gt;</td>
<td>H&lt;sup&gt;4&lt;/sup&gt;</td>
</tr>
<tr>
<td>Repeated over years on same plot (residual effects for 2&lt;sup&gt;nd&lt;/sup&gt; and 3&lt;sup&gt;rd&lt;/sup&gt; year)</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Saravane district (Saravane) and Phonthone district (Champasack)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1&lt;sup&gt;st&lt;/sup&gt; year</td>
<td>0.06</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>2&lt;sup&gt;nd&lt;/sup&gt; year</td>
<td>0.06</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>3&lt;sup&gt;rd&lt;/sup&gt; year</td>
<td>0.06</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>4&lt;sup&gt;th&lt;/sup&gt; year&lt;sup&gt;5&lt;/sup&gt;</td>
<td>0.06</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Xiengkho district (Houaphanh), Vapi district (Saravane) and Peng district (Xayabouli)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1&lt;sup&gt;st&lt;/sup&gt; season</td>
<td>0.06</td>
<td>2</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2&lt;sup&gt;nd&lt;/sup&gt; season</td>
<td>0.06</td>
<td>4</td>
<td>-</td>
<td>-</td>
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<tr>
<td>New sites (no residual effects)</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>0.06</td>
<td>5.2</td>
<td>-</td>
<td>1.3</td>
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<tr>
<td></td>
<td>0.06</td>
<td>2</td>
<td>-</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>0.06</td>
<td>2</td>
<td>-</td>
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</tr>
</tbody>
</table>

<sup>1</sup>N = in-organic N fertilizer (t N), <sup>2</sup>M = manure; <sup>3</sup>S = rice straw; <sup>4</sup>H = rice husk (M, S and H quantities in t/ha based on dry weight)

<sup>5</sup>Phonthon district only

Table 6 Effect of commercial organic fertilizers on rice yields

<table>
<thead>
<tr>
<th>Locations Seasons</th>
<th>Fertilizer (t/ha)</th>
<th>Yield (t/ha)</th>
<th>Yield increase (%)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N&lt;sup&gt;1&lt;/sup&gt;</td>
<td>COF&lt;sup&gt;2&lt;/sup&gt;</td>
<td>N</td>
<td>COF</td>
</tr>
<tr>
<td>2 2</td>
<td>0.06</td>
<td>1.0</td>
<td>2.0</td>
<td>52</td>
</tr>
<tr>
<td>5 3-4</td>
<td>0.06</td>
<td>1.0</td>
<td>2.0</td>
<td>65.8</td>
</tr>
<tr>
<td>12 1</td>
<td>0.07</td>
<td>2.0</td>
<td>2.79</td>
<td>50</td>
</tr>
</tbody>
</table>

<sup>1</sup>N = in-organic N fertilizer in (t N); <sup>2</sup>COF = commercial organic fertilizer in t of fertilizer (1.5-3%)
Table 7. Effect of rock phosphate on rice yields

<table>
<thead>
<tr>
<th>Location</th>
<th>Years after 1st application</th>
<th>Yield (t/ha)</th>
<th>Yield increase (%)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vientiane</td>
<td>0</td>
<td>3.23</td>
<td>6</td>
<td>14</td>
</tr>
<tr>
<td>Vientiane</td>
<td>1</td>
<td>3.5</td>
<td>8</td>
<td>24</td>
</tr>
<tr>
<td>Vientiane</td>
<td>2</td>
<td>2</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Houaphanh</td>
<td>0</td>
<td>4.33</td>
<td>14</td>
<td>3</td>
</tr>
<tr>
<td>Houaphanh</td>
<td>1</td>
<td>3.2</td>
<td>28</td>
<td>25</td>
</tr>
<tr>
<td>Houaphanh</td>
<td>2</td>
<td>3.3</td>
<td>16</td>
<td>35</td>
</tr>
</tbody>
</table>

1Fertilizer application was repeated yearly for Vientiane. For Houaphanh the fertilizer was applied in the first year only
2Tripple supperphosphate applied at the rate of 60 kg P₂O₅/ha
3Rock phosphate, applied at the rate of 320 kg P₂O₅

Table 8. Technologies recommended for soil fertility management

<table>
<thead>
<tr>
<th>Technology recommended</th>
<th>Number of agencies' (n=11)</th>
<th>Recommending technology</th>
<th>Documented results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stop using in-organic chemicals</td>
<td>10</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>Use compost</td>
<td>8</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>Effective microorganism for composting and pest management</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Bio Extracts for pest management</td>
<td>3</td>
<td>3</td>
<td>0</td>
</tr>
</tbody>
</table>

1Agencies recommending technology