Research article

Soil Fertility Management in Rainfed Lowland Rice Eco-systems

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Abstract Rice (*Oryza Sativa* L.) is a staple food of the Cambodian population and accounts for 68-70 percent of daily calorie intake. Rainfed lowland rice ecosystems are often hampered by drought, submergence and soil problems (Acid Sulphate) that are associated with low productivity and with a high incidence of poverty. A study was conducted to identify the best practices in soil fertility management and conservation on sandy soil for improving rice yield and cost effectiveness of rainfed lowland rice production systems in order to contribute to the improvement of food security and income generation of rural farmers. Three experiments were conducted in rainfed lowland rice agro-ecosystems in Champei commune, Bati district of Takeo province from the middle of 2006 to the middle of 2009: (i) assessment of agro-ecosystem analysis and rice agro-ecosystems, (ii) study on interaction and cost-effectiveness of NPK fertilizers and compost on rice yield in sandy soil in rainfed lowland production systems and (iii) on-farm adaptive research on interaction of NPK fertilizers and compost in sandy soil of rainfed lowland rice ecosystems. The results clearly indicated that the factors and parameters impacting on rice productivity and yield are poor soil fertility (sandy loam soil) and poor soil fertility management. Two options of best practices were identified for improving soil fertility management and rice yield. Firstly, for farmers raising a limited number of cattle (1-2 cattle) and limited access to compost fertilizers should use $N_{25}P_{13}K_{15}$ or Urea at 44 kg, DAP 25 kg and KCl 25 kg plus 5 tones of compost per hectare. Secondly, for farmers raising more cattle and producing large amounts of compost fertilizer recommendations are the same with 10 tones of compost per hectare.

Keywords soil fertility, sandy soil, rainfed lowland, rice productivity, Cambodia

INTRODUCTION

Rice, *Oryza sativa* L., is a staple food for the Cambodian population and accounts for 68-70 percent of daily calorie intake. The rice Agro-Ecosystem in Cambodia is categorized according to geographical location, ranging from mountainous to deepwater areas including upland, rainfed lowland, floating rice and dry season rice (Men Sarom, 2007). Rainfed lowland rice ecosystems are often hampered by drought, submergence and soil problems (Acid Sulphate) that are associated with low productivity and with a high incidence of poverty. These ecosystems have many factors and constraints to rice production such as poor soil quality, flood and drought, water problems, pest and diseases and crop management practices of farmers.

Recently increasing fuel and fertilizer prices have also raised concerns for farmers, especially for rice farming, to maintain the delicate balance between sufficient profitability for farmers and sufficient rice supply at affordable prices for the urban and non-farming rural poor. As fertilizer prices increase, research and extension workers often advise farmers to reduce fertilizer use to save money. However, crop yield is directly related to the amount of nutrient taken up by the crop. Use of less of fertilizer means lower crop yield and less profit for farmers. Important questions are: how much fertilizer is needed to maximize profit and how could we improve rice production under these conditions?

To address these constraints, we conducted the research study: "Strategy for Soil Fertility Management in Rainfed Lowland Rice Eco-system in Cambodia". This research aimed to identify the best practices in soil fertility management and conservation on sandy soil for improving rice yield and cost effectiveness of rainfed lowland rice production systems in order to contribute to improved food security and income generation for rural farmers. Objectives of the research were:

1. To identify the problems and constraints in rice production systems and to identify options to address these in rainfed lowland rice eco-system in Cambodia
2. To develop best practices for effective application of NPK fertilizers and compost on rice yield and cost-effectiveness in sandy soil under rainfed lowland production systems in Cambodia
3. To identify the best practices of appropriate fertilizer application, that could be adopted by farmers for improving rice yield and soil fertility management in sandy soil under rainfed lowland rice ecosystems and
4. To develop extension packages or technical implementing procedures (TIP) for extension workers and farmers to use in rice production of rainfed lowland rice ecosystems in Cambodia.

MATERIALS AND METHODS

Three research studies were conducted: (i) agro-ecosystem analysis and rice agro-ecosystems assessment in Champei commune, Bati district of Takeo province; (ii) study of interaction of NPK fertilizers and compost on rice yield and cost effectiveness for production in sandy soil in rainfed lowland rice agro-ecosystems in Cambodia and (iii) adaptive research on farmer fields (on-farm trials) on rice yield and cost effectiveness of production on sandy soil in rainfed lowland rice agro-ecosystems in Cambodia.

Agro-ecosystem and rice eco-systems analysis in Champei commune

Agro-ecosystems analysis (AEA) is a participatory analysis tool used by multi-disciplinary teams in participation with farmers to identify the problems, constraints and impacts on rice production systems and to identify options and measures to overcome these. The assessment used the agro-ecosystems analysis (AEA) tools and methods including secondary data collection (e.g. commune profile), soil sampling and analysis, meteorology data (rainfall and temperatures), rapid rural appraisal (RRA-time line/trend lines, transect walks, seasonal calendars, venn diagrams and problem trees or causes and effect analysis). Check list questionnaires of fertilizer use, soil fertility management, and farming systems were also used with farmer cooperators.

Interaction of NPK fertilizers and compost on rice yield and cost effective rice production

Fertilizer recommendations for the Prateah Lang Soil type in rainfed lowland rice ecosystems in Champei commune are $N_{50}P_{25}K_{30}$, which means 50 kg N, 25 kg P and 30 kg K, with 5 to 10 tones of compost. The improved aromatic rice variety of Phkar Rumduol was selected for the experiments during the wet seasons of 2007 and 2008. Nine different treatment combinations of NPK and compost rates were tested: $N_0P_0K_0$ (T1), 5 t of compost (T2), 10 t of compost (T3), $N_{25}P_{13}K_{15}$ (T4), $N_{25}P_{13}K_{15}$ + 5 t of compost (T5), $N_{25}P_{13}K_{15}$ + 10 t of compost (T6), $N_{50}P_{25}K_{30}$ (T7), $N_{50}P_{25}K_{30}$ + 5 t of compost (T8) and $N_{50}P_{25}K_{30}$ + 10 t of compost (T9).

On-farm adaptive research (on-farm trials) on rice yield and cost effectiveness of production

These experiments were conducted in nine selected farmer fields on sandy loam soils (Prateah Lang soil type) with four selected combinations of NPK and compost: $N_{50}P_{25}K_{30}$, 10 tones of compost, $N_{50}P_{25}K_{30}$ + 10 t of compost and $N_{25}P_{13}K_{15}$ + 10 t of compost. Phkar Rumduol rice variety was also selected for these experiments during the wet seasons of 2007 and 2008.

RESULTS AND DISCUSSION

Agro-ecosystem and rice ecosystem analysis in Champei Commune

Agriculture and soil condition: Based on agro-ecosystem analysis (AEA), rice-based farming is a major occupation in Champei commune and most families also raise cattle and pigs as well as poultry (chicken and ducks). The AEA identified Prateah Lang soil type (red yellow podzol) with 642 ha as the major soil type in the rainfed lowland rice eco-systems in Champei Commune. This was followed by the Bakan soil types (Grey Hydromorphs or Luvisols) covering 585 ha. Kbal Po (Alluvial soil or gleysol) was also found to be a major soil type covering 354 ha in recession rice and irrigated dry season rice areas. The Prateah Lang soil is of low fertility and needs to be improved for better yield and profits. NPK is the major fertilizer used with combinations of Urea, DAP and NPK (16-16-20) at a rate of about 1-2 bags or 50 to 100 kg/ha for wet season rice. Rice yields are in the range of 1.5 to 2.5 tonnes per hectare.

Table 1 Soil properties in main rice soils in Champeir commune, Bati district, Takeo

Soil property	Prateah Lang soil (Red yellow podzol)	Bakan soil (Grey Hydromorph)	Kbal Po soil (Alluvial soil)
Organic matter (OM) %	0.67	1.12	1.8
C %	0.29	0.68	0.91
N %	0.04	0.043	0.10
P (ppm)	21	37	46
K meq/100g soil	0.03	0.07	0.19
pH	4.5-5.1	5.7	5.9

Source: Soil result analysis, September 2007, Soil Lab analysis, General Directorate of Agriculture.

Results of AEA also indicated that the sandy soil in Champei commune is generally low in organic matter content (0.64%), low pH (4.5-5.1), low CEC and low N, P, K, S, and Mg. Some locations have Fe, S and Mn toxicity and poor drainage. Low productivity and low yield of rice in rainfed lowland rice is primarily due to poor soil fertility. Production is often reduced by drought and flood. Production is also limited by poor crop management practices including poor land preparation, poor on-farm water management, poor fertilizer management, poor weed management, use of unpure seed and poor post-harvest practices. Pests, especially an outbreak of brown plant hoppers (BPH), appeared in the 2007 wet season.

Climatic conditions

Rainfall: During the past ten years the average rainfall in Champei commune was 1,249 mm and during 2000 and 2001 the rainfall was higher than previous years. The Commune received 1,555 mm in 2000 and 1,597 mm in 2001. In 2007, rainfall commenced in March and annual total amount was 1,213 mm. However in 2008, rainfall was only 1,040 mm which was lower than the ten year average. Rainfall variability is a constraint for rice production in the rainfed lowland (Fig. 1).
Temperature: The average temperature during the past ten years has not changed much. The peak of the hot season is during April and May (30 ^{o}C). From June to December the average temperature declines from 29 ^{o}C to 26 ^{o}C. Maximum temperatures are high during April-May with 35-36 ^{o}C and declines to 31-33 ^{o}C from June to December. Minimum temperature is less variable (20 ^{o}C to 26 ^{o}C). These temperatures provide good conditions for rice plant growth, especially in the rainfed lowland rice ecosystem (Fig. 2).

These results clearly indicated that the factors and parameters impacting on rice productivity and yield were poor soil fertility (sandy soil) and poor soil fertility management. The study also identified options for improving fertility management on sandy loam soils in rainfed lowland rice ecosystems and identified best practices and cost-effective soil fertility management for improving rice production and quality. Adoption of these practices would contribute to improved household food security and income generation for rural poor farmers.

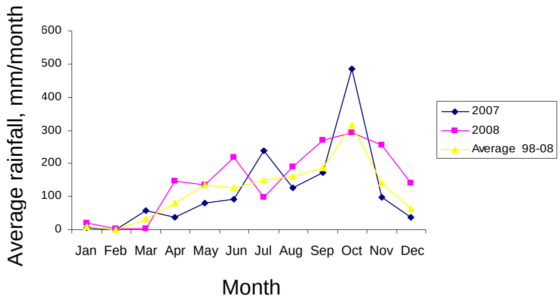

Fig. 1 Average rainfall during 1998-2008 in Bati district

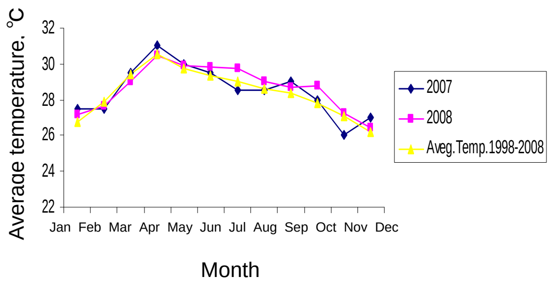

Fig. 2 Monthly average temperature during 1998-2008 in Bati district

Interaction of NPK fertilizers and compost on rice yield and cost effective rice production

The results of fertilizer experiments during the wet season 2007 and 2008 indicated that on sandy soil, the optimum rate of fertilizer application for increasing rice yield is $N_{25}P_{13}K_{15}$ (Urea 44 kg, DAP 25 kg and KCl 25kg) plus 5 to 10 tonnes of compost per hectare. The fertilizer treatments differed significantly for their effect on rice yield ($P<0.01$). $N_{25}P_{13}K_{15}$ plus 10 tones of compost on sandy soils (Prateah Lang Soil) gave a rice yield of 3.50 t/ha in the 2007 wet season and 4.17t/ha in the 2008wet season. $N_{25}P_{13}K_{15}$ plus 5 t of compost gave a yield of 2.81 t/ha in the 2007 wet season and 3.42/ha in the 2008 wet season (Fig. 3).

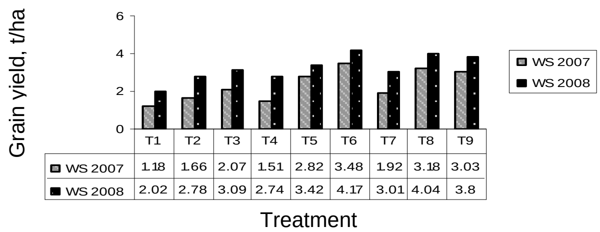

Fig .3 Grain yield for NPK and Compost trials in wet season 2007 and 2008

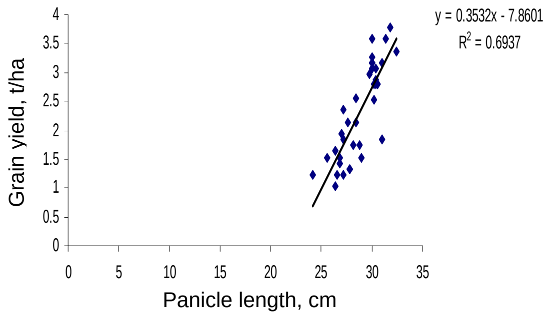

Fig. 4 The correlation between panicle length and yield of experiment 2007

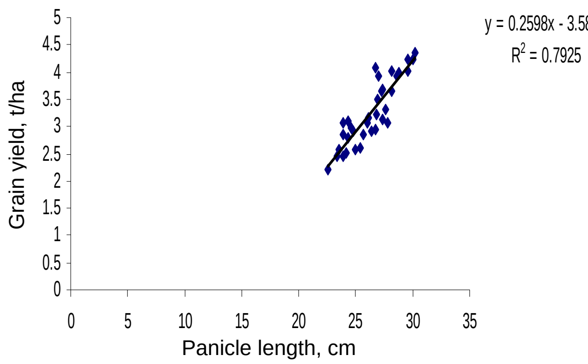

Fig. 5 The correlation between panicle length and yield of experiment 2008.

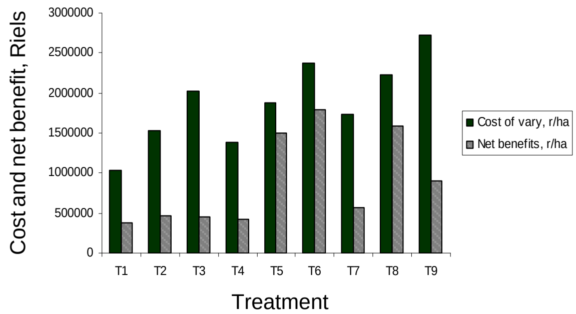

Fig. 6 Net benefit of experiment in wet season 2007

The result of experiment in wet season 2007 and 2008, the correlation between yield component and yield are also indicated that the increasing of yield components is correlation between yield in difference treatment of NPK and compost (Figs. 4 and 5).

The gross margin of both wet season experiments in 2007 and 2008 indicated that $N_{25}P_{13}K_{15}$ or Urea 44 kg, DAP 25 kg and KCl 25 kg plus 10 t of compost gave net profits from US$ 436 to US$ 640 per hectare, respectively. The treatment of $N_{25}P_{13}K_{15}$ or Urea 44 kg, DAP 25 kg and KCl 25 kg plus 5 t of Compost gave net profits from 1.49-2.22 Million KHRiels per hectare in 2007 and 2008 (Figs. 6 and 7).

The purpose of these experiments was to identify economic and environmentally sound practices that could be adopted by farmers with sandy soil in rainfed lowland rice agro-ecosystems. From the results, we concluded that the two best options for improving soil fertility management and rice yield were: (a) farmers with few cattle (1-2 cattle) and limited access to compost fertilizers should use $N_{25}P_{13}K_{15}$ or Urea 44 kg, DAP 25 kg and KCl 25 kg plus 5 t of compost per hectare, (b) farmers with more cattle and compost fertilizers should use $N_{25}P_{13}K_{15}$ or Urea 44 kg, DAP 25 kg and KCl 25 kg plus 10 t of compost per hectare.

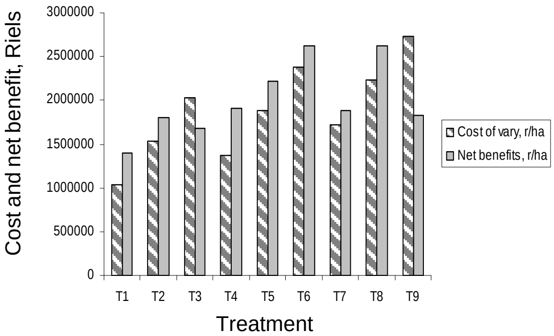

Fig. 7 Net benefit of experiment in wet season 2008

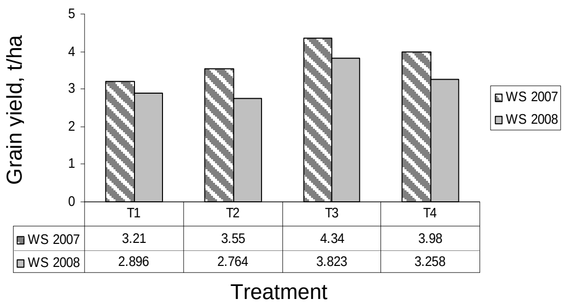

Fig. 8 Grain yield for On-farm adaptive trials of NPK and Compost in wet season 2007 and 2008

On-farm adaptive research (on-farm trials) on rice yield and cost effectiveness of production

The results of on-farm adaptive trials with NPK fertilizers and compost during the wet seasons of 2007 and 2008 showed that the optimal rate of fertilizer application for better rice yield and profit was $N_{25}P_{13}K_{15}$ (Urea 44 kg, DAP 25 kg and KCl 25 kg) plus 10 t of compost per hectare (Fig. 8).

The recommended rate ($N_{50}P_{15}K_{30}$) and 10 t of compost per hectare gave low rice yield and benefit. In fact, half the recommendation rate ($N_{25}P_{13}K_{15}$) plus 10 t of compost on sandy soil gave a higher rice yield (Phkar Rumduol variety) of 4.34 t/ha and net profit per hectare at US$ 690 in 2007 and 3.82 t/ha and net profit at US$538 in 2008 (Figs. 9 and 10). $N_{25}P_{13}K_{15}$ or Urea 44 kg, DAP 25 kg and KCl 25 kg plus 10 t of compost gave a net profit per hectare at US$ 692 in 2007 and US$ 540 in 2008, respectively.

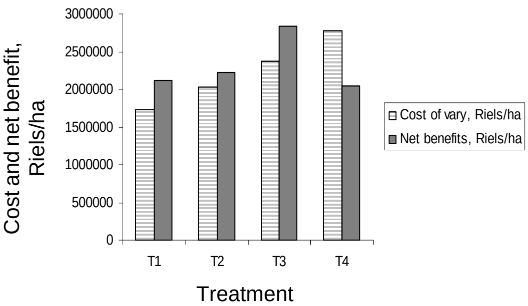

Fig. 9 Net benefit of on-farm experiment in wet season 2007

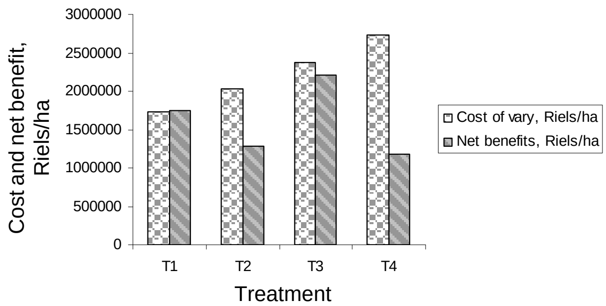

Fig. 10 Net benefit of on-farm experiment in wet season 2008

CONCLUSION

The results showed that use of chemical fertilizer (NPK) alone on sandy soil did not improve soil and crop productivity. Chemical fertilizer alone has potential negative impacts on soil structure and texture, micro-organisms in the soil and mineral toxicity to underground water. However use of organic fertilizer alone on sandy soil also has low effects on soil fertility and crop yield. These effects have become clear after only several years of continuous applications of organic fertilizers (compost). Two options for best farming practice in rainfed lowland rice are: (1) farmers with few cattle (1-2 cattle) and limited access to compost fertilizers should use $N_{25}P_{13}K_{15}$ or Urea 44 kg, DAP 25 kg and KCl 25 kg plus 5 tonnes of compost per hectare (2) farmers with available cattle and compost fertilizers should use $N_{25}P_{13}K_{15}$ or Urea 44 kg, DAP 25 kg and KCl 25 kg plus 5 t of compost per hectare. The results of these experiments were also used to develop best practice extension packages or technical implementing procedures (TIPs). These are used by researchers, extension workers and farmers for improving soil fertility management and conservation, and rice production in the sandy soils of rainfed lowland rice ecosystems in Cambodia. The collection of organic manure also results in cleaner households, farms and villages and therefore improved hygiene and sanitation.

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