Increasing and stabilizing grain yields in rice production systems on a gradient of complexity

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Background

Attempts to increase food crop yields by intensifying agricultural systems using high inputs of non-renewable resources and chemicals frequently lead to degradation of natural resources, whereas most technological innovations are not accessible for smallholders that represent the majority of farmers world-wide. Alternatively, cocultures consisting of assemblages of plant and animal species can support ecological processes of nutrient cycling and pest control, which may lead to increasing yields and declining susceptibility to extreme weather conditions with increasing complexity of the systems.

Introduction

Complex agricultural systems consisting of assemblages of plant and animal species can support ecological processes of nutrient cycling and pest control, which may lead to higher yields and reduced susceptibility to extreme weather conditions when the complexity of the systems increases. However, there is a lack of scientific knowledge concerning agro-ecological processes of plant growth and development, effectiveness of pest suppression, nutrient cycling, and the productive performance of agricultural systems on gradients of complexity and under extreme conditions.

Methods

An on-farm field experiment was conducted between September 1 and December 12, 2010, in Pagelaran, Malang district, East Java, Indonesia (8°10'27"S, 112°35'58"E), 335 m.a.s.l. on a clay-loam soil. The experimental layout was a randomized block design with two replicate blocks. The control treatment consisted of rice only (R), the other eight treatments consisted of combinations of nutrient management (compost (+C) and compost and azolla (+C+A)) and pest management (ducks (+D) and ducks and fish (+D+F)).

Results

- For all pests the size of the population was largest for the rice-only treatment, and lower for the more complex combinations of system production factors (Figure 1). In particular the presence of ducks reduced the pest abundance.
- Rice plants in the more complex treatment combinations had higher leaf expansion rates and reduced plant stress as indicated by the lower values for biomass dry matter content and specific leaf area.
- Total biomass and grain yield increased with larger system complexity (Figure 2). The highest grain was obtained in the most complex system comprising compost, azolla, ducks and fish.
- Both ducks and fish improved nitrogen cycling, only ducks contributed to potassium cycling and that ducks and fish did not affect the phosphorus cycling in the various rice cultivation systems.
- More complex systems required extra investments to purchase the applied production factors of young ducks and fish. However, these investments were more than compensated by the additional revenues from the sales of the better yielding rice grain and the mature ducks and fish.

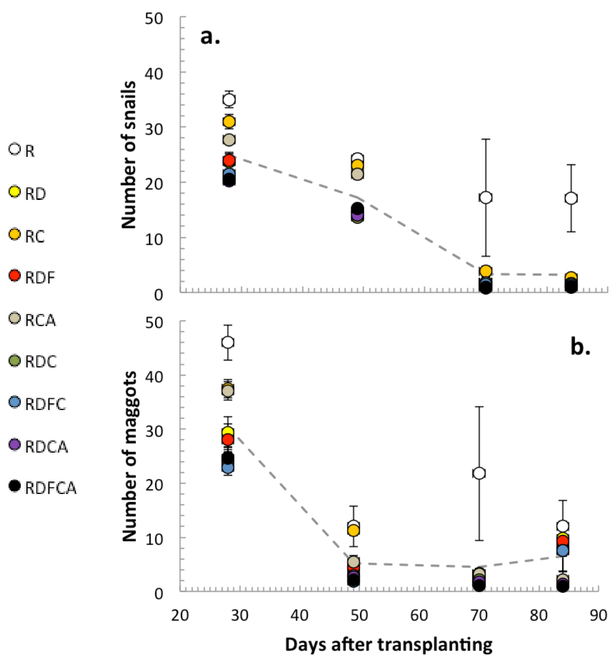
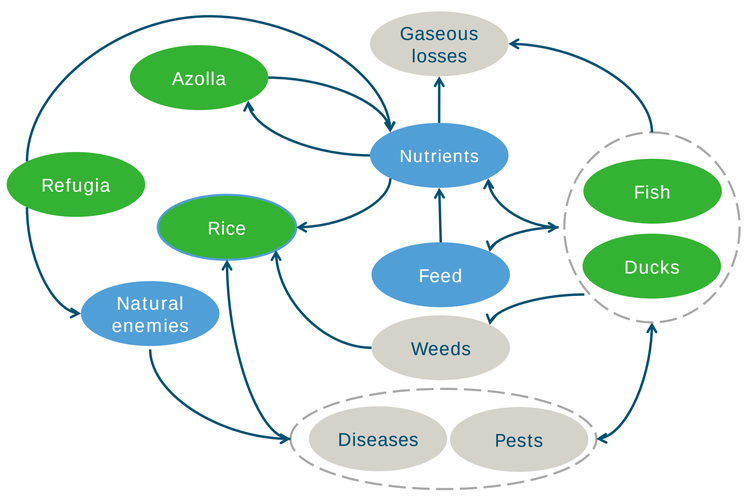


Figure 1. Abundance of plant pests per hill (± standard error of mean), a. snails (*Bellamya javanica*), b. rice whorl maggots (*Nephotettix virescens*). R = rice, D = with ducks, C = with compost, F = with fish, A = with azolla.



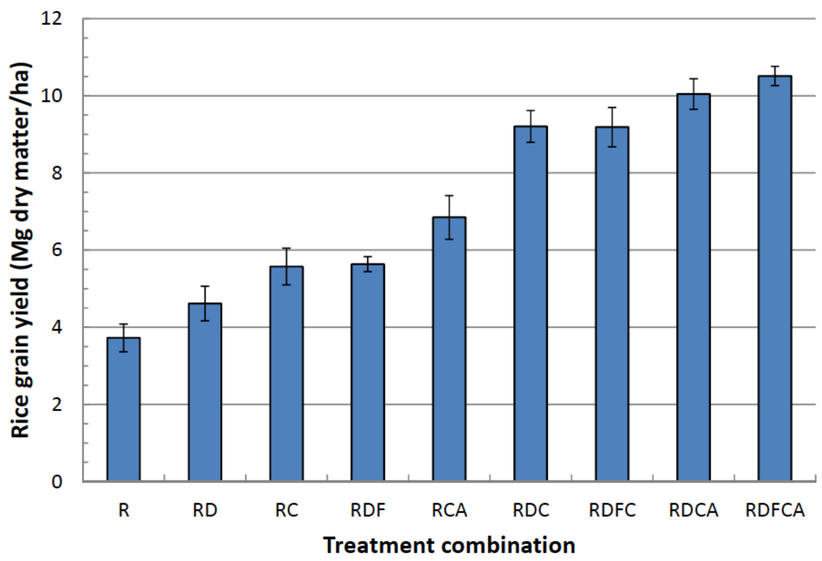


Figure 2. Yield of rice grain for increasingly complex rice cultivation systems (± standard error of mean). R = rice, D = with ducks, C = with compost, F = with fish, A = with azolla. Error bars represent standard error of the mean (n=10).

Conclusions

- Enhancing the complexity of a rice production system resulted in strongly increased grain yields and revenues in a season with extremely adverse weather conditions on East Java, Indonesia.
- Complex agricultural systems can contribute to food security in a changing climate.
- If smallholders can be trained to manage these systems and are supported for initial investments by credits, their livelihoods can be improved while producing in an ecologically benign way.

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