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The application of best management practices increases the profitability and sustainability of rice farming in the central plains of Thailand

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ABSTRACT

There is a need to increase the resource use efficiency and sustainability of rice production in the intensive lowland irrigated rice growing areas of Thailand where farmers face challenges such as the overuse of inputs that cause negative environmental effects, rising input and labor costs, declining rice farm gate prices, and water scarcity. Since 2012, a set of integrated best management practices based on Cost Reduction Operating Principles (CROP) has been promoted to rice farmers by the Thailand Rice Department. Through replicated farmer participatory field trials, we evaluated the performance over three seasons of three integrated best management packages that included CROP recommendations, CROP + alternate wetting and drying (AWD), and CROP + drum seeder (DS) technology and compared these with standard farmer's practice (FP). We also provide an economic and productivity assessment of the large-scale (160–800 ha) application of CROP practices across eight sites in the Chao Phraya river basin. In the field trials, farmers that applied CROP practices reduced fertilizer inputs by a mean of 50–64% per season with no yield penalty and were able to increase their net income versus FP by a mean of 26% across all three seasons. The CROP + DS treatments also reduced seed rates by 60–67% and consistently showed the largest benefits over FP, with increases in mean net income per season in the range of 29–46%. Due to water shortages in the dry season, all treatments followed forced-AWD. However, even with limited water supply, high yields were still attained across all plots, giving farmers the assurance that yields can be maintained with AWD practices. Results from the large-scale application of CROP practices showed farmer groups reduced costs by 6–36% ($\bar{x}$ = 17%) and increased net income by 21–131% ($\bar{x}$ = 79%) when compared with the same season in the previous year. The results of these studies indicate that through an increase in income and a decrease in inputs that cause negative environmental impacts, the adoption of improved agronomic practices can enhance the sustainability of intensive rice production.

1. Introduction

In Asia, the growing human population and decreasing agricultural land area have intensified the global pressure to increase food production in remaining agricultural land (GRiSP, 2013). However, agricultural intensification has led to an increased use of chemical and organic inputs, which are associated with a number of negative environmental effects such as climate change, a degrading natural environment, and biodiversity loss (Lobell et al., 2009; Mueller et al., 2012; Phalan et al., 2014). In addition, the high use of inputs to maximize yield is in most cases not the most economically profitable practice for farmers as it can increase the susceptibility of rice plants to pests and diseases, especially when inputs are applied excessively or unnecessarily (Altieri, 2002; Heong et al., 2013; Ma et al., 2014; West et al., 2014). For long-term agricultural sustain-

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ability, farm management practices that have a negative effect on both the environment and on farmers' profit margin should be avoided. Overall, farmers should use practices that are able to sustain current agricultural productivity but avert degradation of the environment that may lead to loss in productivity over the long term (Altieri, 2002).

Thailand is one of the world's largest producers and exporters of rice, with the major rice growing areas located in the north-east region and in the lower north and central plains of the Chao Phraya river basin. Roughly 70% of the rice area in Thailand is rainfed, but the irrigated area, located mainly in the Chao Phraya river basin, accounts for 49% of the total annual rice production (Kupkanchanakul, 2000; USDA-FAS, 2015b). A recent study by Stuart et al. (2016) in Nakhon Sawan province within the central plains of Thailand found that rice farmers were over-applying nitrogen (N) fertilizer and that their mean farm yield during the wet season (WS) of 2013 was 1.4 t ha^{-1} (or 23.3%) lower than the attainable farm yield (the mean yield of the top decile). Although this yield gap is relatively small compared to the yield gap in some regions in other Southeast Asian countries, there is clearly potential for rice farmers in this region to reduce their inputs and increase their yields.

The rice industry in Thailand is facing a number of challenges that threaten its sustainability. In 2014, rice farmers faced a 50% decline in farm gate prices for rice as a result of falling domestic rice prices and of the discontinuation of the Thai Government's rice pledging scheme (USDA-FAS, 2015a; Attavanich, 2016). The rice-growing area in the Chao Phraya river basin also is identified as a hot-spot of water scarcity due to increased competition with urban and industrial users (Bouman et al., 2007). This became apparent between early 2013 and mid-2016, when rice farmers in the Chao Phraya river basin faced irrigation restrictions and water shortages due to low reservoir levels and below-average rainfall (USDA-FAS, 2015b). This, coupled with rising rural wages and input costs, has magnified the focus on increasing the resource use efficiency and sustainability of rice production in a region where water shortages are becoming increasingly likely.

Since 2012, the Thailand Rice Department (TRD) has promoted a set of integrated best management practices based on the Cost Reduction Operating Principles (CROP). CROP practices aim to increase income by 20% by reducing costs whilst maintaining or increasing yields by following the "Three must do" and "Three must reduce" recommendations. This is similar to the "Three Reductions, Three Gains" crop management technology that was introduced to rice farmers in Vietnam which has since evolved into 'One Must Do Five Reductions' (Huan et al., 2005; Huelgas and Templeton, 2010). For CROP, the "Three must do" recommendations include 1) planting no more than two crops per year, 2) using high-quality seeds, and 3) recording farming production costs and income in a diary. On the other hand, the "Three must reduce" recommendations include reducing 1) seed rate applications, 2) incorrect fertilizer application practices, and 3) unnecessary chemical applications.

As part of an adaptive farmer participatory research platform, we established replicated production-scale field trials of three integrated best management packages that included CROP recommendations, alternate wetting and drying (AWD) and drum seeding (DS) technologies. In this paper, we evaluate the performance of these different sets of "best practices" against farmer's practice in relation to yield, resource use efficiency, and profitability. The main objectives of this study were to reduce the economic and environmental costs of rice production and promote water-saving technologies whilst at the same time increasing or maintaining productivity. In addition, we provide an economic and productivity assessment of the application of CROP on a large scale in several sites in the Chao Phraya river basin.

Table 1
Baseline soil properties at 0–15 cm soil depths in the field trial sites in Nakhon Sawan, Thailand.

Soil properties	Range	Mean ± S.D.
pH (1:1 soil:water)	5.42–7.21	6.08 ± 0.69
EC (dS m^{-1}) (1:1 soil:water)	0.02–0.15	0.06 ± 0.04
Soil Organic Matter (%)	1.64–4.13	2.99 ± 0.79
Available P (mg kg^{-1})	5.2–54.5	17.8 ± 16.8
Exchangeable K (mg kg^{-1})	170–326	232 ± 53

2. Methods

2.1. Experimental site

Farmer participatory field trials were established in Nong Jikree and Sapansong villages in Nakhon Sawan province in the central plains of the Chao Phraya river basin (15°12′N 100°21′E) where rice farming is the primary livelihood. Each village site had established Community Rice Centers that are rice farmer groups who are registered with the government extension office and who interact with local extension specialists (Soitong, 2010). Rice is grown twice a year: the first or wet season (WS) crop is from June to October and the second or dry season (DS) crop is from January to May. The mean farm size is 4.9 ha (±1.2 SE), with a mostly clay soil type (Stuart et al., 2016; Table 1). The main crop establishment method is wet direct-seeding using a mechanical knapsack sprayer. Due to labor scarcity, a majority of the farmers in these areas practice farm mechanization, from land preparation to harvesting. The overuse of production inputs such as fertilizers, seeds, and pesticides is one of the current inefficient practices in the region (Stuart et al., 2016; unpublished data).

2.2. Experimental design and treatment details

To account for spatial variability, a randomized complete block design was established, consisting of four treatments in each block replicated over three sites for the 2013 DS and eight sites for the 2014 WS (Table 2). The four treatments applied were (i) CROP, (ii) CROP + AWD, (iii) CROP + DS, and (iv) Farmer's Practice (FP). These treatments were selected to address the main needs identified by the farmers during focus group discussions in both villages. In each block, one to two farmers were selected, depending on their field size, to apply the CROP treatments and another farmer was selected to follow FP in a neighboring field. This was to minimize the transfer of CROP practices to the FP field. Farmers were selected based on the willingness to participate in the field trials. All farmers in each block planted the same rice variety. Two blocks (including the same farmers) were common throughout all three seasons. One block was common for the first two seasons and another block was common for the latter two seasons. After the end of each season, meetings were held with participating farmers to evaluate the technologies and practices and to facilitate farmer learning in an adaptive research approach (Flor et al., 2016). At the maturing stage of the second and third season rice crops, farmer field days were held to promote the CROP practices, AWD, and drum seeder technology to the wider community.

In the 2015 DS, low reservoir levels led to irrigation restrictions that prohibited the planting of a dry season crop. For the 2015 WS, low reservoir levels and below-average rainfall restricted rice planting only to areas reached by irrigation water. Hence, for the 2015 WS, field trials were established only in Nong Jik Ree village due to its close proximity to the main irrigation canal and only three treatments per block were applied: CROP, CROP + DS, and FP. These blocks were replicated over three sites.

For all the CROP treatment fields, land preparation, fertilizer application, and pest management followed CROP recommenda-