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On-farm testing of a nutrient management decision-support tool for rice in the Senegal River valley

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ABSTRACT

We evaluated recommendations provided by a cloud-based decision-support tool named Nutrient Manager for Rice (NMR) in terms of yield of irrigated lowland rice and profitability in comparison with farmers' fertilizer management practices (FFP) in the Senegal River valley. A total of 102 on-farm trials were conducted over the three seasons (2011 wet season, and 2012 and 2013 dry seasons). On average in each season, NMR recommendations increased rice yield by 1–2.3 t/ha and profitability by US$ 216–640 per ha compared to FFP. Differences between FFP and NMR performance were mainly related to timing of the top-dressing of N fertilizer (delayed in the case of FFP), the number of N fertilizer applications (generally just one top-dressing for FFP; two or three for NMR), and application of K. We conclude that NMR offers a promising avenue for increasing the productivity and profitability of irrigated lowland rice in the Senegal River valley.

1. Introduction

In Senegal, only about 40% of total rice (*Oryza* spp.) consumption is satisfied through domestic production (ANSD, 2011). High dependence on imported rice renders the country vulnerable to international market shocks with severe consequences for food security and political stability (Seck et al., 2010). The Senegalese government aims to increase rice production through support to irrigated-rice farmers in the Senegal River valley (SRV). Average rice yield is generally high in both wet and dry seasons at 5.4 and 6.6 t/ha, respectively; however, there is large variation among farmers (e.g. Wopereis et al., 1999; Poussin et al., 2003). Wopereis et al. (1999) report that yield gaps between potential yield simulated by the ecophysiological crop model ORYZA_S (Dingkuhn, 1995; Dingkuhn and Sow, 1997) and actual yields obtained by farmers ranged from 1.8 to 8.2 t/ha, suggesting that there was large scope for improving rice yield in this area. It has been reported that farmers generally did not follow recommended sowing time, fertilizer rates, and timings – they generally sowed late, applied late and in excess (Wopereis et al., 1999; Poussin et al., 2003; Tanaka et al., 2015). Following these findings, Haefele et al. (2000, 2001) conducted on-farm trials and found that improved nutrient management increased yields by about 1 t/ha in farmers' fields.

Based on these numerous studies, recommended N rates by Société Nationale d'Aménagement et d'Exploitation des Terres du Delta du fleuve Sénégal et des Vallées du fleuve Sénégal (SAED) range from 133 to 179 kg/ha, applied as di-ammonium phosphate (DAP) at around sowing or transplanting, and three splits of urea (at early tillering, panicle initiation, and booting) (SAED, personal communication). Differences in application rates depend on season and agro-ecological zone. The recommended rate is higher in the dry season (Haefele and Wopereis, 2004), and higher in the Senegal River delta than in the middle valley, where extreme temperatures tend to occur and affect potential yield. Recommended P_2O_5 and K_2O rates are 46 and 0 kg/ha, respectively. K_2O fertilizer application is not recommended because K inputs from irrigation water and from dust depositions are considered sufficient (Haefele and Wopereis, 2004). In a previous study, K_2O fertilizer application was recommended when target yield was 8 t/ha or

Abbreviations: AE_N, targeted agronomic efficiency of N fertilizer; AEZ, agro-ecological zone; DAP, di-ammonium phosphate; DAS, days after sowing; FFP, farmers' fertilizer practice; FK, K fertilizer requirement; FN, N fertilizer requirement; FP, P fertilizer requirement; GY, target grain yield; GY_{0N}, grain yield without N fertilizer; K_{CR}, K retained in residue from previous crop; NMR, Nutrient Manager for Rice; P_A, P from atmospheric deposition; P_{CR}, P retained in residue from previous crop; RIE, reciprocal internal efficiency; SRV, Senegal River valley; SSNM, site-specific nutrient management.

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more (Haefele and Wopereis, 2004). But, when this recommendation was developed, most of farmers did not carry out double cropping and target high yield.

Most rice farmers in Africa depend on blanket recommendations, despite the fact that optimal amounts and sources of nutrients to meet the needs of the crop depend on many factors, such as indigenous soil nutrient supply, variety choice, and target yield. Scientists at the West Africa Rice Development Association (WARDA, now Africa Rice Center [AfricaRice]) developed variety-, site- and season-specific recommendations on nutrient management for irrigated lowland rice in Burkina Faso, Mali, and Senegal (Haefele et al., 2003; Haefele and Wopereis, 2004; Segda et al., 2005). Simulation models such as ORYZA_S and RIDEV were used to determine potential yield level as a function of sowing date, location, and variety choice (Dingkuhn, 1995; Dingkuhn and Sow, 1997). However, none of these approaches allowed for field-specific recommendations.

Recent advances in information technology and mobile communications make it possible for extension workers and farmers to generate variety-, field-, and season-specific recommendations on crop management practices for rice by using a smartphone or tablet. The International Rice Research Institute (IRRI) has developed a cloud-based decision-support tool named Nutrient Manager for Rice (NMR) to deal with such specificity and provide farmers with field-specific nutrient management recommendations before the cropping season (the version currently in the public domain is called Crop Manager; http://cropmanager.irri.org/). This approach relies on the scientific principles determined during 15 years of site-specific nutrient management (SSNM) research across Asia (e.g. Dobermann et al., 2002; Buresh et al., 2010). NMR provides advice on when, how much, and what sort of fertilizer to apply. NMR can be accessed through a personal computer, smartphone, or tablet by agricultural extension officers or lead farmers. The recommendations are calculated from farmers' replies to questions about the agro-ecological or administrative zone of their field, the variety of rice, availability of irrigation water, previous crop and management of its residue, previous rice yield levels, and fertilizer use. Although information is still limited on the impact of NMR on yield and profitability in Asia, it has been reported in the Philippines that fertilizer management based on NMR increased yield by 0.37 t/ha per season (Gabinete and Buresh, 2013). This gain was similar to values observed in previous studies on SSNM in Asia (Dobermann et al., 2002). IRRI and AfricaRice have worked together to develop NMR for the SRV through the use of data on yields from previous fertilizer trials in irrigated lowland rice in West Africa for estimating indigenous N supply (e.g. Wopereis et al., 1999; Haefele and Wopereis, 2004), potential yield and optimum sowing windows (Dingkuhn and Sow, 1997), and expert knowledge on crop duration of popular varieties and crop management in the SRV. This paper describes the framework of NMR developed for the SRV and reports on its evaluation on farm during three growing seasons (2011 wet season, and 2012 and 2013 dry seasons). The objective of this work was to compare rice yields obtained using NMR recommendations with yields obtained by farmers not using the tool (FFP).

2. Material and methods

2.1. Description of the study area

The Senegal River valley (SRV) is located in the tropical – warm/arid zone (Saito et al., 2013). Five agro-ecological zones (AEZs) are locally distinguished in this area (Haefele and Wopereis, 2004). In this study, we considered AEZ I and AEZ II as the Senegal River delta, and AEZ III and AEZ IV as the Senegal River middle valley. Average annual rainfall is about 200 mm with one rainy season (July–September). Solar radiation is high and for a large part of the year ranges from 20 to 30 MJ/(m^2 day). Temperature is variable across AEZs, but the coastal area is cooler than the continental area (Dingkuhn, 1995). Soils are generally course to medium textured in the delta, and medium to fine textured in the middle valley (Haefele and Wopereis, 2004). The irrigated lowland rice production system in this study area has been described in numerous studies (e.g. Wopereis et al., 1999; Haefele and Wopereis, 2004).

2.2. Framework of Nutrient Manager for Rice for the Senegal River valley

NMR for SRV has been developed by IRRI as an HTML5 application which means it can be accessed through a web browser, using any of the major operating systems with equal effectiveness, from a smartphone or a personal computer (http://webapps.irri.org/nm/wa/). For this paper, we used NMR pre-release version 1. The NMR recommendations are based on information obtained on the following:

- Agro-ecological zone (i.e. Senegal River delta or middle valley)
- Size of the field
- Number of rice crops to be cultivated per year (one or two)
- Season (wet or dry)
- Rice variety to be sown
- Crop establishment method (transplanted or direct seeded)
- Approximate rice yields in previous seasons
- Portion of residues from previous crop retained in the field (i.e. short or long stubble)
- Expected water supply level during rice growing season (adequate or inadequate)
- The type of fertilizers to be or already purchased.

A flow chart for determining N, P, and K fertilizer application rates and timing is shown in Fig. 1. White boxes indicate input data obtained from previous studies, reported by experts in this region, or calculated intermediate outputs. Gray and black boxes indicate input information from farmers and outputs, respectively. Potential yield and crop duration were calculated from information on season, AEZ, choice of variety, and crop establishment method. In previous studies, these were determined using the crop model ORYZA_S with variety-specific photo-thermal parameters using long-term historical weather data (Haefele and Wopereis, 2004). We used expert knowledge on potential yield and crop duration based on observation at the research stations of AfricaRice in the delta and middle valley, as photo-thermal parameters of new varieties are unavailable. Rice growth stages (e.g. panicle initiation, booting) were then empirically determined using information on crop duration of each variety (e.g. panicle initiation equals crop duration minus 60 days). Potential yield of all the varieties in the Senegal River delta was estimated at 9 and 10 t/ha in wet and dry seasons, respectively, and potential yield was taken as 8 t/ha for both seasons in the middle valley. Target yield is determined by a farmer's answers concerning yield level on the same field during previous seasons, and maximum target yield set at 80% of potential yield, as the risk of lowering profitability is higher when target yield is above 80% (Haefele et al., 2003). If there is a large gap between 80% of potential and the farmer's yield level, NMR will propose a large yield increase from the current level. If the gap is small, NMR will propose a small yield increase up to 80% of potential. Also, farmers can modify the target yield, when they are not satisfied with target yield or fertilizer application rate. In this study, difference in target yield and the previous yield level reported by farmers ranged from almost zero to 5 t/ha.