Fertilizer Use Efficiency and Profitability of Irrigated Rice in Mali and Niger

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Background

- Rice is a strategic crop for food security in West Africa, but lowland rice yields vary widely with a current mean of 4.1 Mg ha^{-1} which is <50% of potential mean yield.
- Poor quality seed and agronomic practices, low fertilizer use, pests and diseases are constraints.
- Fertilizer use is needed to achieve high yield.
- Information for determination of nutrient response functions for irrigated rice was inadequate.
- Such functions are needed to maximize fertilizer use profit.

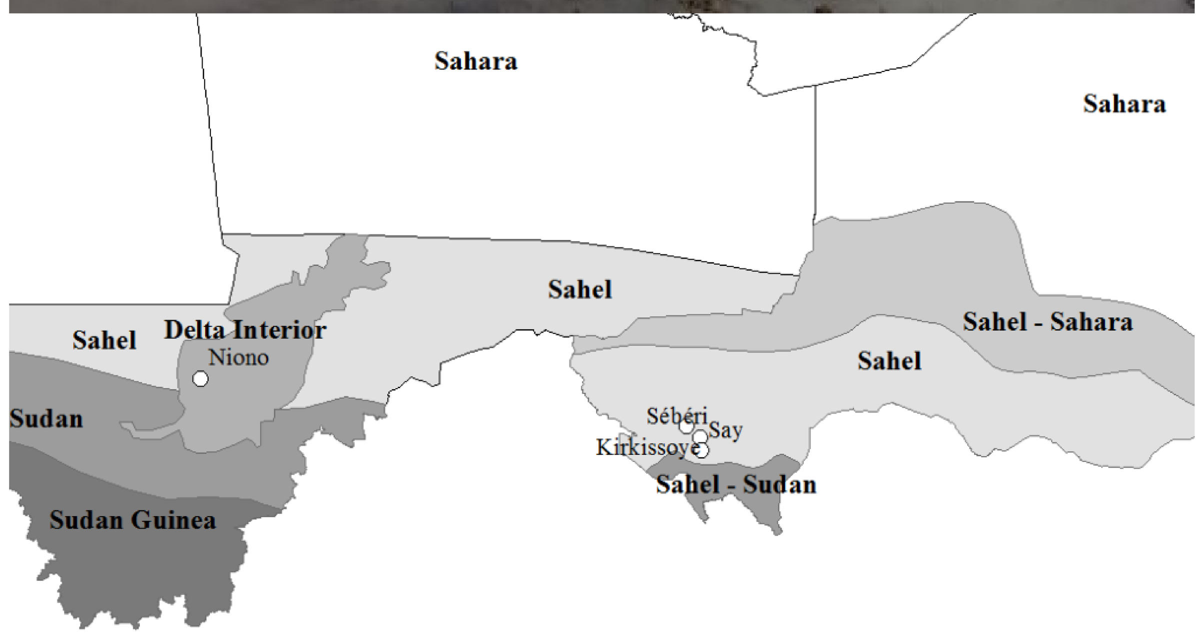

Figure 1 Study sites

Objectives

1. Determine nutrient response functions for N, P and K of irrigated rice in the Niger River valley;
2. Diagnose other nutrient deficiencies; and
3. Determine the economic opportunities for farmers from fertilizer applied to irrigated rice.

Site Characteristics

- Soil were Fluvisols in Niger and Gleyic (Moursi) and Chromic (Danga) Inceptisols in Mali.
- Mean seasonal temperature of about 29°C for Niger and 26°C for Mali.
- Soil (0-20cm) properties: clay; 6.0-7.5 pH, <10 g kg^{-1} orgC; <1 g kg^{-1} orgN; 5-24 mg kg^{-1} Mehlich-3 P; 0.1-0.3 cmol kg^{-1} K; 9.2-20.3 mg kg^{-1} S; 1.9-4.5 cmol kg^{-1} Mg, 0.1-0.2 mg kg^{-1} B; 2.0-5.4 mg kg^{-1} Zn.

Experimental Design; Data Collection and Analysis

- Incomplete factorial with 16 treatments: 5 N levels with 0 and 15 (Niger) or 20 (Mali) kg ha^{-1} P; 4 P levels; and 4 K levels. The rate increments were 40 kg for N, 7.5 (Niger) or 10 (Mali) kg P; and 10 kg K. A diagnostic treatment for assessment of other deficiencies with 120, 15, 20, 15, 10, 2.5 and 0.5 kg ha^{-1} of N, P, K, S, Mg, Zn, and B for comparison with the treatment 120N-15P-20K. P and K rate effects were evaluated with N and N plus P uniformly applied, respectively.
- RCBD with three replications; varieties were Gambiaca in Niger and Kogoni in Mali.
- Grain yield was determined at harvest from 13 m^2.
- Analysis of variance was across trials within a country using Statistix 10.
- Curvilinear to plateau responses determined: Yield (Mg ha^{-1}) = $a - b*c^n$, where a is yield at the plateau, b is the amplitude (the gain in yield due to nutrient application), c^n determines the shape of the curvilinear curve where c is the curvature coefficient and n was the nutrient rate applied. If the results did not fit the asymptotic function, quadratic and linear functions were attempted.
- The economically optimal rates (EOR) were determined as the nutrient rates to maximize profit per hectare from fertilizer use.
- Agronomic efficiency (AE; yield gain per unit nutrient applied, kg kg^{-1}) and profit to cost ratio (PCR, net profit gain divided by fertilizer use cost) of N and P use was assessed. The PCR were determined with the cost of one kg of N and P use equal to 3 and 5 kg of rice grain, respectively.

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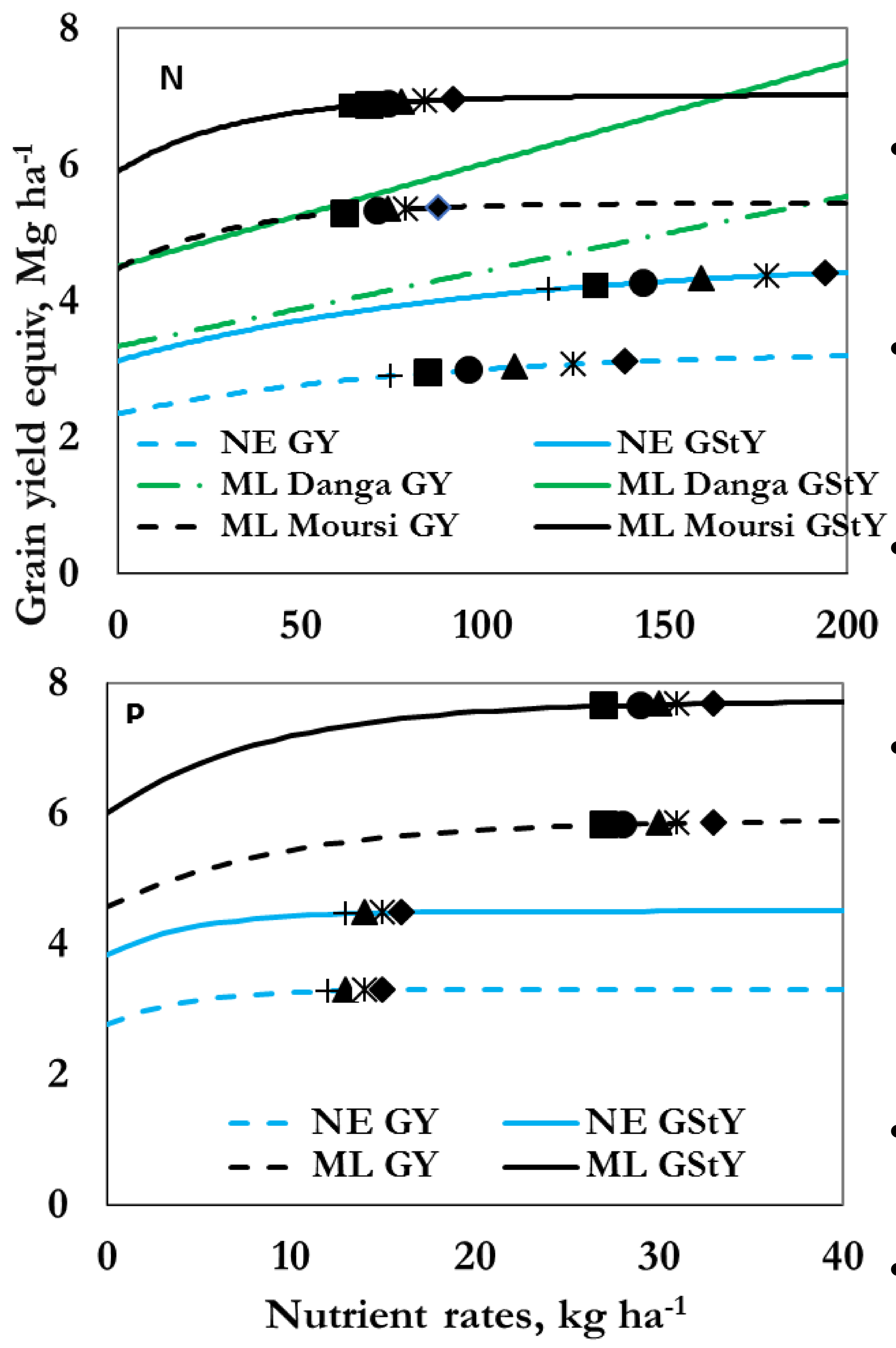

Figure 2. Grain (GY) and grain plus straw (GStY) yield response curves and EOR for N and P applied to irrigated rice on two soil types in Mali (ML) and for three locations in Niger (NE).

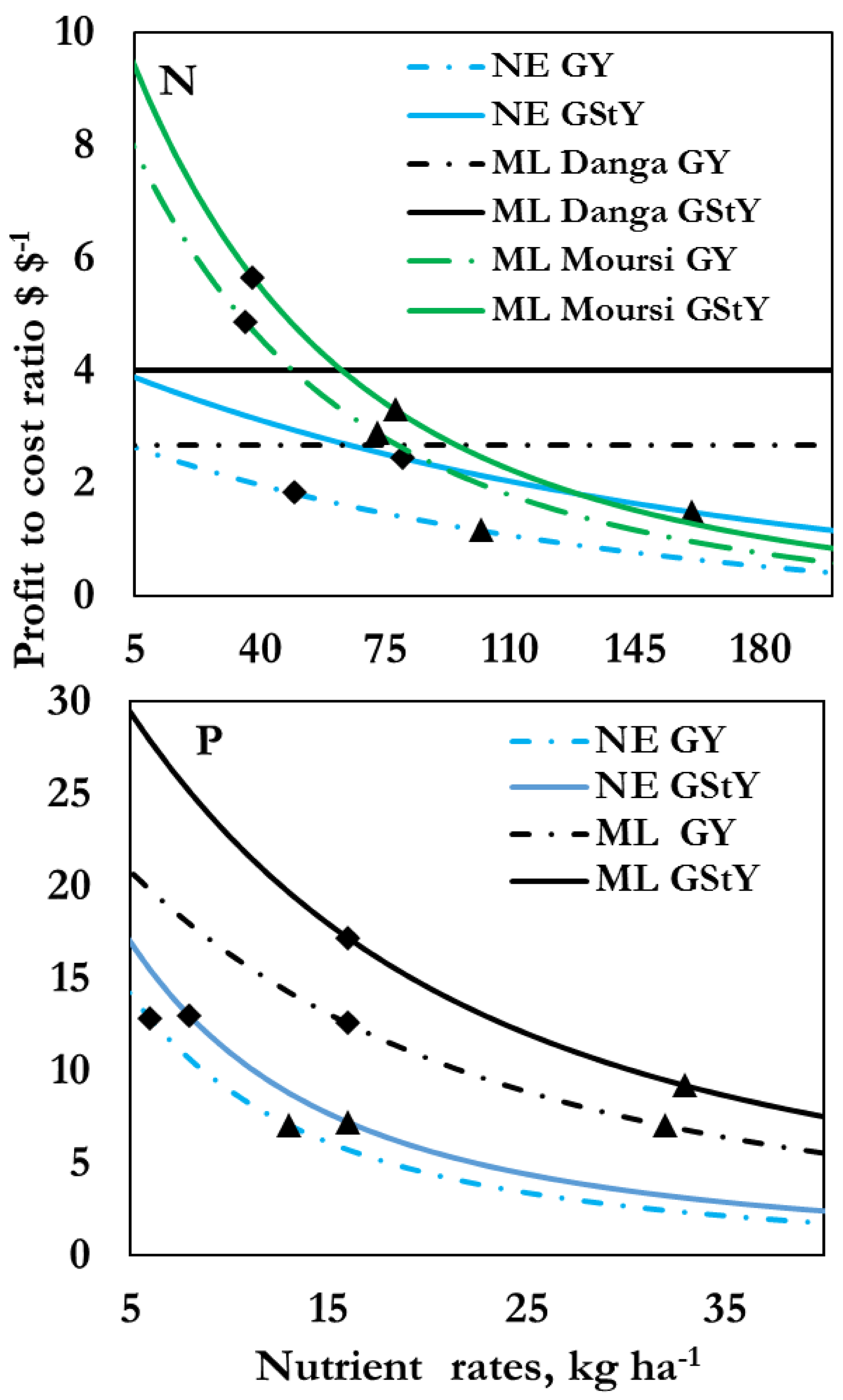

Figure 3. Profit cost ratio for 50% (♦) and 100% (▲) of EOR for N and P, for grain (GY) and grain plus straw (GStY) yield for irrigated rice on average in Niger and on two soil types in Mali.

Results

- Mean grain yields were 3.07, 4.09 and 5.49 Mg ha^{-1} in Niger and on Danga and Moursi soil types in Mali, respectively.
- Response to N was curvilinear to plateau in all cases except for a linear response for Danga soil in Mali. Yield increases ranged from 0.5 to 1.7 Mg ha^{-1} (Fig. 2, 3).
- Response to P was curvilinear with grain yield increases of approximately 0.3 and 1.7 Mg ha^{-1} in Niger and Mali, respectively, with 30 kg ha^{-1} P.
- In Mali, the K response was linear and the diagnostic treatment increased grain yield by 0.97 Mg ha^{-1} overall. Straw yield was not affected by the diagnostic treatment and the harvest index was low indicating that one or more of the diagnostic nutrients was deficient during later reproductive growth stages.
- In Niger, grain yield was not affected by K or the diagnostic treatment.
- The EOR for N when N use cost equaled 4.5 times the grain value (kg kg^{-1}) ranged from 62 to > 150 kg ha^{-1}.
- The EOR of P ranged from 27 to 33 kg ha^{-1} in Mali and from 12 to 16 kg ha^{-1} in Niger, depending on the relative cost of fertilizer P.
- Agronomic efficiency of N varied from <10 to 20 kg kg^{-1}, and of P at 10 kg ha^{-1} from 49 to 95 kg kg^{-1}, depending on location.
- The PCR at EOR of N was >1 and of P use was >5.

Conclusions

- Nutrient response functions for irrigated rice in the Sahel were determined.
- Fertilizer N and P use has good profit potential.
- Responses to applied nutrients were highly consistent across the three Niger sites giving high confidence in application of the response functions in fertilizer use decisions.
- In Mali, the responses were positive but inconsistent in magnitude and shape across the two soil types. More information is needed for fertilizer use optimization.
- The EOR of N and P occurred near the yield plateau. Financially constrained farmers may be wise to apply nutrients at approximately 50% of EOR over more land as the PCR will be 1.7 greater for both N and P compared with 100% EOR.
- The results were used in developing recommendation domain specific fertilizer decision support tools, (https://agronomy.unl.edu/OFRA)
- Study of S and B application at panicle initiation is needed.

References: Niang et al. 2017. Field Crops Res. 207:1-2; Sanders and Shapiro. 2006. Agron. Monograph no. 23., 2nd ed. Madison WI, pp. 879–900; Wopereis et al. 2013. Realizing Africa's rice promise. CABI, Wallingford UK

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