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FARMERS' PERCEPTIONS, PRACTICES AND PERFORMANCE IN A SAHELIAN IRRIGATED RICE SCHEME

By S. M. HAEFELE†¶, M. C. S. WOPEREIS† *and* C. DONOVAN‡

†*West Africa Rice Development Association, BP 96, St. Louis, Senegal and*
‡ *Michigan State University, Department of Agricultural Economics, East Lansing Michigan 49924, USA*

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SUMMARY

Combined socio-economic and agronomic surveys were conducted during two growing seasons with 20 rice (*Orgyza sativa*) farmers in the irrigation scheme of Guédé, northern Senegal. Farmers' knowledge of recommended cropping practices was relatively poor. The surveys identified sub-optimal timing of N fertilizer application and late harvesting as major constraints. Before the start of the second season, farmers were given field-specific recommendations on timing of key crop-management interventions. Average yield compared with the first season increased by more than 1 t ha^{-1}, which was attributed to a slightly higher recovery efficiency of fertilizer N (REN) (average: 0.47 kg crop N kg^{-1} fertilizer N), a change in cultivars used (resulting in a better uptake of indigenous soil N) and more favourable weather conditions in general. It is concluded that if farmers are given better access to information, improved rice technologies, inputs and decision making, rice production on irrigated land in West Africa may leap forward rapidly, as potential production gains are still large.

INTRODUCTION

Irrigated rice (*Oryza sativa*) production in the Sahel accounts for a large share (17%) of the total production in West Africa on a relatively small fraction (7%) of the total rice cultivated area (WARDA, 1999). The agricultural performance of these systems, however, still falls short of expectations. Average yields are around 4 t ha^{-1}, with the notable exception of Mali and Niger where yields reach 5 to 6 t ha^{-1} and Nigeria where yield is below 3 t ha^{-1}. Only about 10 to 20% of the surface area under irrigation is double-cropped in the Sahel. The relatively demanding cropping calendar leaves little room for delays in activities. Labour is often a limiting factor and mechanization is relatively widespread. In Senegal and Mauritania, large parts of irrigated systems developed for rice are not used currently. In the Senegal River valley, 70 000 ha have been developed for irrigated agriculture, of which 60 000 ha could be used immediately without major rehabilitation costs. In 1998, however, only 25 000 ha of irrigated rice were grown in the Senegal River valley.

¶ Corresponding author. E-mail: Warda-Sahel@metissacana.sn

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The liberalization of cereal markets in Sahelian countries has created a new environment for domestic rice production. Before liberalization, public institutions provided seed, water, fertilizer and herbicides, and bought and processed rice. In many countries, new agents (farmer organizations, traders) are now gradually taking over most of the responsibilities that were once under state control. In areas where the expected take-over by the private sector is not yet effective, availability and accessibility of agricultural inputs may become a constraint (Gerner *et al.*, 1998). Fagade (1997) reported that Nigerian rice farmers have major problems buying fertilizer, resulting in low fertilizer application rates and depressed production levels in irrigated systems in northern Nigeria.

Wopereis *et al.* (1999) and Donovan *et al.* (1999) showed that gaps between actual and potential yields in irrigated systems in the Sahelian and savanna agro-ecological zones are usually large, and that major increases in rice productivity are possible through improved crop management practices and improved fertilizer recovery rates. They showed that the recovery of N fertilizer used in farmers' fields is on average only 30%; that is, 70% of the fertilizer applied to the plant is lost. Fertilizers account for 20 to 25% of total production costs in irrigated rice systems in West Africa. Improving the recovery of fertilizers will often increase yields, without major changes in input levels. Current fertilizer recommendations in irrigated systems in the Sahel are extended in 'blanket fashion' that do not take into account variability in soil type, previous management, cultivar choice and growing season. The partial productivity of fertilizer can be improved through better timing of nutrient applications and adjustments of the quantities applied to match native soil fertility. These more knowledge-based integrated nutrient management systems are expected to increase the productivity of fertilizer investments by farmers. In farmers' fields in Senegal and Mauritania, improved soil fertility and improved weed management resulted in a 2 t ha^{-1} yield gain, or 80% increase in net benefits accruing to farmers (Haefele *et al.*, 2000).

For a group of farmers in a representative rice producing irrigation scheme in the Sahel, the objectives of this research were: (i) to assess farmers' knowledge of best-bet crop management recommendations; (ii) to determine actual crop management practices and their agronomic performance; (iii) to determine farmers' perceptions of major constraints affecting their rice crop; and (iv) to deduce the main agronomic and socio-economic contributors to farmers' yields and input productivity.

MATERIALS AND METHODS

Site description

The irrigation scheme of Guédé (594 ha, of which about 400 ha is in use for rice) is located near Podor (16°35′N, 15°02′W), in the Senegal River valley in Senegal. Established in 1939, it is one of the oldest irrigation schemes in this river valley. The scheme was rehabilitated from 1993 to 1995. With the liberalization of the rice production sector in June 1995, responsibility for water management and

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irrigation and drainage infrastructure maintenance was transferred from the Senegalese irrigation and extension authority, 'Société Nationale d'Aménagement et d'Exploitation des Terres du Delta du Fleuve Sénégal et des Vallées du Fleuve Sénégal et de la Falémé' (SAED) to the Guédé farmers' organization.

Agronomic surveys

Surveys were conducted during the 1996 and 1997 wet seasons (July–December). Voluntary participants were identified by SAED. From the volunteers, 20 participants that lived close to main roads (to secure accessibility) and distributed over the entire irrigation scheme were selected. During the wet seasons, no crop other than rice was grown by participating farmers. Originally it was envisaged that the study would also include the 1997 dry season. However, credit problems prevented farmers from growing a second crop on the same field during that season.

In both seasons, the 20 participants were asked to establish two 10×10 m plots in their field (alongside the irrigation canal) that received no fertilization (T_0 plots), but otherwise were managed as usual by the farmer. The rest of the field was managed according to farmers' own choice of fertilizer management (T_F). Farmers were reimbursed the value of yield loss from the T_0 plots and cost of bund construction and maintenance. Five topsoil samples (0.0 to 0.2 m depth; one from each plot corner and one from the centre) were taken in each T_0 plot before the onset of each growing season and composited. They were analysed for pH_{H2O} (1:2.5 extract), 1:5 soil-extract electrical conductivity (EC), P Bray1, and exchangeable K using methods described by van Reeuwijk (1992). Rice yields, and above-ground crop N, P and K uptake were determined at maturity in T_0 plots and in farmers' fields (T_F). Methodologies used are described by Wopereis *et al.* (1999) and Donovan *et al.* (1999). Fertilizer N recovery (REN) was calculated as the difference in N uptake between T_0 and T_F. Internal efficiency of N (IEN) was determined for T_0 and T_F plots as yield divided by total above-ground N uptake.

The rice phenology simulation model RIDEV (Dingkuhn, 1997) was used to determine optimal timing of N fertilizer application (three splits, coinciding with the start of tillering, panicle initiation and heading), timing of drainage for harvesting (two weeks after flowering) and timing of harvest (at physiological maturity) for every combination of sowing date, cultivar choice and season observed in the surveys. These simulations, using 30 years of historical weather data for Podor (a town 10 km away), were compared with actual timing of crop management interventions in both seasons. Potential rice yields, limited by solar radiation and temperature only, were estimated using the rice growth simulation model ORYZAS (Dingkuhn and Sow, 1997) for every combination of sowing date, transplanting date, cultivar choice and season observed in the surveys and actual 1996 and 1997 weather data measured in Fanaye (WARDA's research station close to Podor). ORYZAS and RIDEV were developed by WARDA for the Sahelian and Sudanese savanna regions of West Africa. Yield gaps were determined as the difference between actual farmers' yield and simulated potential yield. Statistical analyses followed Gomez and Gomez (1983) and used STATISTICA software.

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Socio-economic surveys

Surveys covering the same farmers as described above were conducted before, during and after the 1996 wet season, and during and after the 1997 wet season. The 1996 pre-season survey was used to determine farmers' knowledge of crop management recommendations as extended by SAED. The second survey determined actual farmers' practices and information on prices and costs sufficient for partial budgeting of fertilizer input use. Fertilizer applications were evaluated for their returns and their costs, on a per hectare basis, using the T_0 and T_F plots. The increase in yield of T_F plots over T_0 plots was determined for each farmer. The quantity was then reduced by any harvest-related in-kind costs that are sensitive to yield, that is, harvest and post-harvest costs that are charged as a percentage of yield. In Guédé, harvesting, threshing and bagging are based on yield and paid in grain at a rate of 20% of the total harvested; thus 20% of the additional production was deducted. Yield increase was then multiplied by grain price (100 West African Franc [FCFA] kg^{-1}) to estimate gross added product of fertilizers. For fertilizer costs, the quantity of fertilizer applied was valued at the price paid by the farmer. To cover transport, interest and finance charges for the capital used (or the opportunity cost of capital when own capital was used), and labour costs for application, 16% of purchase cost was added. The 16% figure was based on a scenario of interest rate of 6% for the 6-month seasonal period (12% annually), transport costs of 3500FCFA per tonne for fertilizers, and 1000FCFA per day labour costs with two man-days ha^{-1} per application (including transport time). The 6% interest rate reflects current agricultural lending rates. Including the interest costs in the 16% means that all returns are estimated as returns to own capital and labour (Crawford and Kamuanga, 1991). Over the period of the presented surveys, the average exchange rate was US$1.00 = 500FCFA. Cumulative distribution functions of returns were plotted to help identify risk (Hardaker *et al.*, 1997), although these should be interpreted with care given the limited size of the data set.

During the post-harvest survey, farmers were asked to rank their three major constraints in decreasing order of importance. These were given a weighting factor of 0.5 (most important constraint), 0.33 (second most important constraint) and 0.17 (third constraint). Average weights (%) were then determined for each constraint mentioned by farmers.

Farmers' meetings

At critical development stages of the rice crop (panicle initiation, flowering) farmers discussed the crop stand in the field with representatives of SAED and WARDA. End-of-season meetings were also held to discuss the survey results. At the onset of the 1997 wet season (WS), RIDEV-based recommendations on timing of the crop management interventions of weed and fertilizer management, last drainage before harvest and harvest were given to farmers as a function of choice of cultivar and sowing date.

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Table 1. Summary of farmers' knowledge of crop management recommendations at the onset of the 1996 wet season

	Unit	SAED[1] recommendation	Most-frequent answer	Range of answers
Sowing date		1.7 to 15.8	1.7	20.5 to 31.7
Seed for direct seeding	kg ha^{-1}	120	120	100 to 150
Seed for transplanting	kg ha^{-1}	40 to 45	40	40 to 45
Time of transplanting	DAS[2]	20 to 25	20 to 25	20 to 35
Transplanting density	m	0.2 × 0.2,	0.2 × 0.2	0.15 × 0.15 to 0.3 × 0.3
Plants per hill	n	2 to 3	3	1 to 4
Total urea to apply	kg ha^{-1}	250	200	200 to 417
Timing 1 N split				
Transplanting	DAT [3]	22	15	6 to 35
Direct seeding	DAS	30	20	20 to 45
Timing 2 N split	DAT	52	45	30 to 60
Transplanting	DAS	60	60	40 to 90
Direct seeding				
Urea dose 1 split	kg ha^{-1}	165 (0.66%)	100	100 to 250
Urea dose 2 split	kg ha^{-1}	85 (0.33%)	100	100 to 200
Total P to apply	kg ha^{-1}	25 to 30	20	10 to 80
Timing of P to apply				
Transplanting	DAT	−2	15	−2 to 30
Direct seeding	DAS	−2	−2	−2 to 45
Timing 1 chem. weeding	DAT	3	−5	−7 to 5
Transplanting	DAS	21 latest	15	10 to 30
Direct seeding				
Dose propanyl (360) [4]	l ha^{-1}	8 to 10	8	8 to 10
Dose Weedone (480) [4]	l ha^{-1}	1.5 to 2	1	1
Dose Ronstar (120) [4]	l ha^{-1}	6	2	1 to 8
Dose Furadan (10%)	kg ha^{-1}	20	10	2 to 25
Timing of last drainage	DAS	15 days after flowering	shortly before harvest	between 85% maturity and harvest
Timing of harvest		80% maturity	maturity	80% to 100% maturity

[1] according to the regional irrigation and extension authority SAED.
[2] DAS: days after sowing.
[3] DAT: days after transplanting.
[4] numbers in brackets = active ingredients in g l^{-1}.

RESULTS

Farmers' knowledge

Farmers' knowledge of crop management recommendations is summarized in Table 1. Farmers were clearly aware of the importance of starting the season on time (before 15 August for a short-duration variety and before 5 August for a

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medium-duration variety) to avoid spikelet sterility due to cold stress around flowering. All farmers also agreed on the amount of seed to be used (40 kg ha^{-1}) to establish a nursery. They were less clear about the optimal age of seedlings at transplanting (20–35 d after sowing), and transplanting density (0.15×0.15m to 0.3×0.3m). The greatest discrepancies between SAED recommendations and farmers' knowledge were for fertilizer and weed management practices (dosage and timing), timing of drainage before harvest and harvesting.

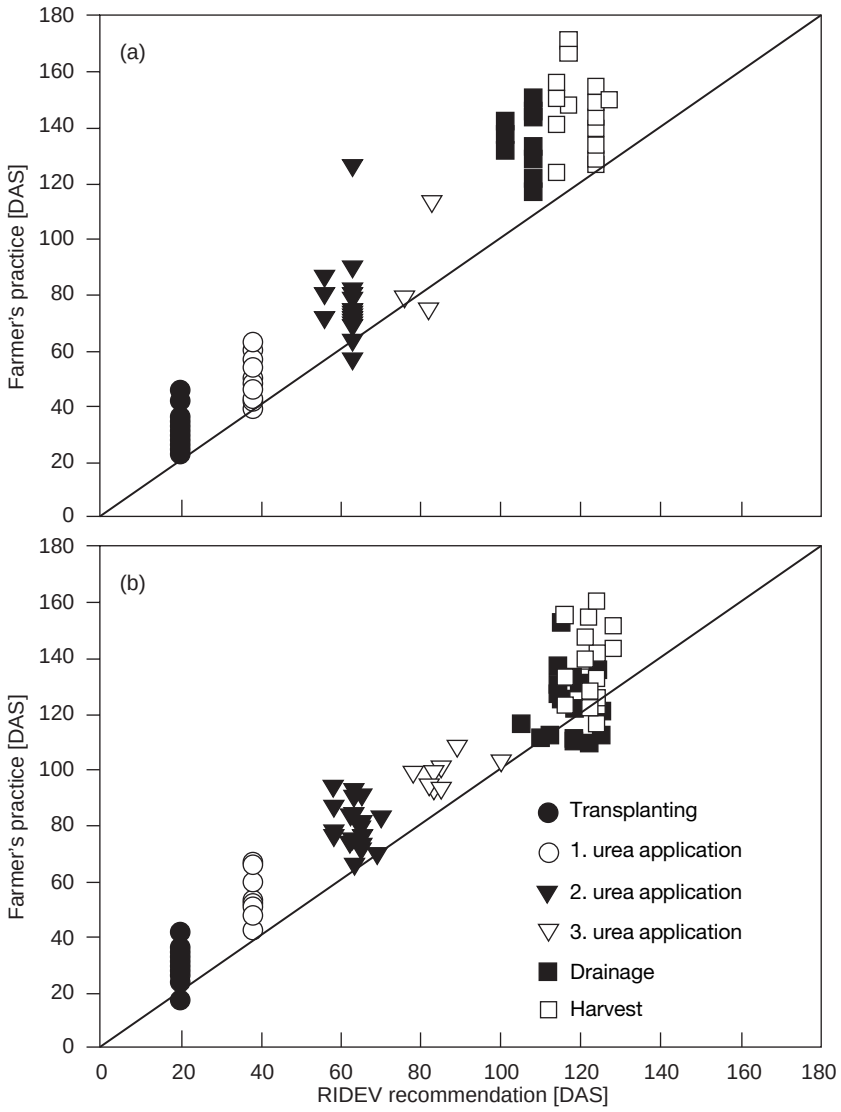


Fig. 1. Actual timing of farmer's practice in comparison with optimal timing of crop management interventions during the 1996 wet season (a) and the 1997 wet season (b) in days after sowing (DAS). Optimal timing was derived using the RIDEV simulation model as described in the text.

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Farmers' practices and performance

All study farmers transplanted 30-day-old rice seedlings in both seasons. In 1996, they used two medium-duration cultivars, Jaya (17 farmers) and IKP (3 farmers). In 1997, three 'Sahel cultivars' released by WARDA and partners in the Senegal River valley in 1994 and IR1529 partly replaced Jaya and IKP. Four farmers transplanted the short-duration cultivar IR13240-108-3-2, released as Sahel108, one farmer used medium-duration BW293-2, known as Sahel201, another farmer used medium-duration ITA306 released as Sahel202, and two farmers transplanted medium-duration IR1529. The remaining 12 farmers in 1997 used Jaya. The only short-duration cultivar among the cultivars grown by the Guédé farmers, Sahel108, reduces growth duration in the wet season by about 15 days compared with a medium-duration cultivar.

Comparison of actual and optimal (according to RIDEV) timing of crop management interventions revealed that almost all interventions were carried out too late (Figure 1). Lack of information on optimal timing, and problems with access to inputs such as credit, seed and fertilizer are among the main reasons that were cited by farmers during meetings after the 1996 season. In 1997, a slightly better fit between farmer- and RIDEV-recommended timing was obtained, most probably as a result of the field-specific recommendations given during the farmers' meetings at the onset of the 1997 wet season. All farmers practised chemical weeding before transplanting and most farmers also practised manual weeding, on average 20 d after transplanting. Insecticides were used mainly in the 1996 wet season.

Soil test results, presented in Table 2, showed that available K levels were low, that is, within the range of critical levels (0.1–0.4 cmol kg^{-1} exchangeable K) reported by Dobermann *et al.* (1995). Values for pH and electrical conductivity (EC) were within a favourable range for rice growth. Several fields showed a low soil-P status. Haefele *et al.* (2001) indicated that in the Senegal River valley P availability becomes a limiting factor for rice crops at P Bray1 values below 4 mg kg^{-1}.

Farmers applied almost identical amounts of N in both seasons (about 115 kg ha^{-1}), mostly in two splits in 1996, but with almost half of the farmers applying a third split in 1997 (Table 3). This was most probably a result of the RIDEV recommendations given to the farmers before the start of the 1997 wet season.

Table 2. Descriptive statistics of top soil characteristics (0.0 to 0.2 m depth) in Guédé, Senegal, for the fields of all twenty participants in the 1996 wet season.

	Unit	Mean	SD*	Maximum	Minimum
pH (1:2.5 extract)		6.0	0.4	6.6	5.2
EC (1:5 extract)	mS cm^{-1}	0.2	0.3	1.1	0
P Bray1	mg kg^{-1}	4.7	5.6	17.9	0.9
Ca	cmol kg^{-1}	12.6	3.3	18.8	7.8
Mg	cmol kg^{-1}	7.5	2.3	11.7	4.0
K	cmol kg^{-1}	0.4	0.1	0.6	0.2
Na	cmol kg^{-1}	0.6	0.4	1.7	0.3

* standard deviation

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Table 3. Descriptive statistics of key crop management parameters in Guédé, Senegal, during the 1996 and 1997 wet seasons. In addition, above-ground nutrient uptake in unfertilized plots (T_0) and in farmers' fields (T_F), simulated potential yields, internal efficiency of N (IEN) and recovery efficiency of applied N (REN) are shown.

		Wet season 1996			Wet season 1997		
	Units	Cases	Mean	SD	Cases	Mean	SD
Sowing date		20	25.7	2.0	20	28.6	9.2
Transplanting date	DAS [1]	20	31	6.5	20	31	5.8
Harvest date	DAS	20	144	12.6	20	134	13.8
1. Chemical weeding (Ronstar)	DAT [2]	20	−2	2.0	20	−4	3.6
1. Chemical weeding (Ronstar)	kg ha^{-1}	20	2	0.3	20	1	0.2
Manual weeding	DAT	16	20	12.8	10	21	15.0
Insecticide (Furadan)	kg ha^{-1}	18	7	4.3	1	3	
1. Dose urea topdressed	kg ha^{-1}	20	104	17	20	85	21
2. Dose urea topdressed	kg ha^{-1}	20	94	20	20	97	37
3. Dose urea topdressed	kg ha^{-1}	3	99	48	9	62	21
1. Dose DAP [3]	kg ha^{-1}	20	80	21	15	102	30
2. Dose DAP	kg ha^{-1}	9	59	34	1	50	
1. Dose DAP basal	DAT	1	−10		2	−10	3.5
1. Dose DAP topdressed	DAT	19	18	5.8	13	21	4.6
2. Dose DAP topdressed	DAT	9	51	5.8	1	81	
Applied N	kg ha^{-1}	20	117	23.2	20	111	20.1
Applied P	kg ha^{-1}	20	22	6.2	15	21	6.6
Applied K	kg ha^{-1}	1	25		0		
T_0 yield	t ha^{-1}	20	2.87	0.95	20	3.08	1.33
T_F yield	t ha^{-1}	20	5.57	1.05	19	6.66	1.35
Yield increase	t ha^{-1}	20	2.70	1.19	19	3.38	1.34
Plant N T_0	kg ha^{-1}	20	31	11.0	20	33	12.4
Plant N T_F	kg ha^{-1}	20	82	15.1	20	85	21.9
Plant P T_0	kg ha^{-1}	20	9	3.4	–	–	–
Plant P T_F	kg ha^{-1}	20	20	4.9	–	–	–
Plant K T_0	kg ha^{-1}	20	57	20.5	20	58	28.7
Plant K T_F	kg ha^{-1}	20	155	44.3	19	143	30.9
Simulated yield	t ha^{-1}	19	7.46	0.44	20	8.04	0.66
Simulated duration	days	20	123	7.4	20	130	7.2
IEN T_0	kg kg^{-1}	20	94	10.9	19	92	21.9
IEN T_F	kg kg^{-1}	20	68	7.5	19	80	8.5
REN	%	20	44	14.9	20	47	17.8

[1] DAS: days after sowing.
[2] DAT: days after transplanting.
[3] DAP: di-ammonium-phosphate.

The amount of P used was similar in both seasons (about 20 kg ha^{-1}), mostly top-dressed in one or two splits (1996), or one split (1997) as recommended by SAED. Only one farmer applied K, and that was in the 1996 wet season. Harvesting in 1997 was on average 10 d earlier than during the 1996 wet season although the mean simulated cycle duration in 1997 was 7 d longer. Timing of harvest, therefore, was much closer to physiological maturity of the rice crop.

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Table 4. Internal efficiency of nitrogen (IEN) and related factors in Guédé, Senegal, during the 1996 and 1997 wet seasons. Analysis of nitrogen-related factors was separated for the 'old' cultivars Jaya and IKP and the 'new' cultivars Sahel and IR and for unfertilized (T_0) and fertilized plots (T_F).

Season	WS 1996	*s. e.*	WS 1997	*s. e.*	WS 1997	*s. e.*
Variety	Jaya+IKP		Jaya+IKP		Sahel+IR	
No. of cases	20		11		8	
N applied (kg ha^{-1})	117.2	5.5	104.4	5.4	120.9	5.5
P applied (kg ha^{-1})	21.8	1.0	15.3	3.1	18.4	2.1
Plant N T_0[1] (kg ha^{-1})	31.0	2.6	29.0	2.1	42.7	6.1
Plant N T_F[1] (kg ha^{-1})	81.6	4.7	76.1	4.7	99.7	4.9
IEN T_0 (kg grain kg^{-1} plant N)	93.6	4.5	93.9	4.3	89.5	7.0
IEN T_F (kg grain kg^{-1} plant N)	68.5	1.8	83.0	2.3	73.7	2.0
REN[2] (%)	44.3	4.1	45.9	4.2	48.2	4.3
Yield T_0 (t ha^{-1})	2.87	0.28	2.83	0.27	3.58	0.50
Yield T_F (t ha^{-1})	5.57	0.27	6.23	0.31	7.33	0.39

[1] total above-ground plant N uptake at maturity.
[2] REN: recovery efficiency of N applied.

Average crop N, P and K uptakes were very similar in both seasons for both T_0 and T_F plots (Table 3). However, yields were much higher in the 1997 season, with average farmers' yields of 5.6 t ha^{-1} in 1996 and 6.7 t ha^{-1} in 1997. A closer look revealed that the newly released cultivars (Sahel cultivars and IR1529) consistently outperformed the 'old' cultivar Jaya in 1997 (Table 4). The new cultivars had a significantly higher crop N uptake in the T_0 plots, indicating a better use of indigenous soil N supply. Similar results were obtained in a N-use efficiency trial with different cultivars at WARDA's research farm in Ndiaye (unpublished data), where the Sahel cultivars also outperformed Jaya on non-fertilized and fertilized plots. In addition, the REN of the new cultivars in 1997 was slightly higher than the REN for the old cultivars in both seasons (Table 4).

The relation between grain yield and N uptake (called internal efficiency of N; IEN) for both seasons is plotted in Figure 2. The authors added envelope lines for maximum dilution and accumulation of N in modern rice cultivars i.e. the maximum and minimum grain yield per above-ground plant N uptake, as defined by Cassman *et al.* (1997). Observations for T_0 plots were close to the line of maximum dilution in both seasons. T_F observations were centred mostly between the maximum dilution and accumulation lines, indicating relatively balanced N supply and demand. Average IEN values for T_0 and T_F plots are given in Table 3.

The ORYZAS model was used to calculate potential yields for every farmer in both seasons (from the combination of sowing date, cultivar used and weather data of the year concerned). Average simulated potential yield in 1996 was 7.5 t ha^{-1} and about 0.5 t ha^{-1} higher in 1997 (Table 3). This compares with an increase in farmers' yields (T_F) from 5.6 t ha^{-1} in 1996 to 6.7 t ha^{-1} in 1997.

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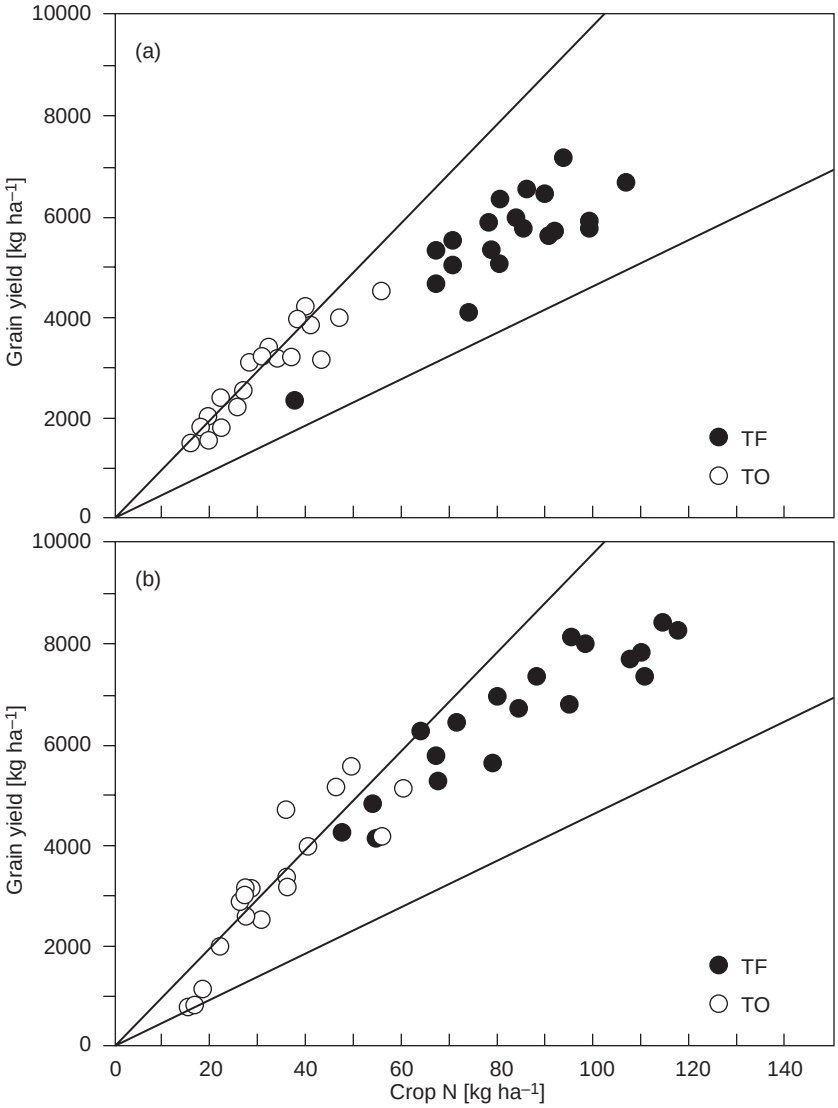


Fig. 2. Relation between grain yield and total above-ground N uptake for unfertilized plots (T_0) and farmers' practice (T_F) at the survey sites in Guédé, Senegal during (a) the 1996 and (b) the 1997 wet seasons. Added are envelope lines for maximum dilution and accumulation of N in modern rice cultivars as defined by Cassman *et al.* (1997).

Net benefits to fertilizer use were mostly very positive, as indicated in Figure 3 and Table 5. Similar results were reported by Donovan *et al.* (1999). Net benefits of fertilizer use increased from 155 000FCFA ha^{-1} in 1996 to 209 000FCFA ha^{-1} in 1997. The value:cost ratio also increased, from 3.6 to 4.5 (Table 5), indicating the high profitability of fertilizer use.

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Table 5. Descriptive statistics of economic results in Guédé, Senegal, for the 1996 and 1997 wet seasons. Calculated was a partial budget for fertilizer use, i.e., only costs and benefits due to fertilizer use were evaluated.

		1996		1997	
	Units	Mean	SD	Mean	SD
Total costs of fertilizer	000 FCFA[4] ha^{-1}	61	12	61	12
Harvest costs of yield increase	000 FCFA ha^{-1}	54	24	67	28
Gross added product[1]	000 FCFA ha^{-1}	216	95	270	110
Added net benefit[2]	000 FCFA ha^{-1}	155	94	209	106
Value:cost ratio[3]		3.6	1.6	4.5	1.6

[1] gross added product: paddy price x yield increase – additional costs caused by higher yield.
[2] added net benefit: gross added product – total costs of fertilizer.
[3] value:cost ratio: added net benefit:total costs of fertilizer.
[4] US$1.00 was valued on average at 500FCFA (West African franc) during the survey period.

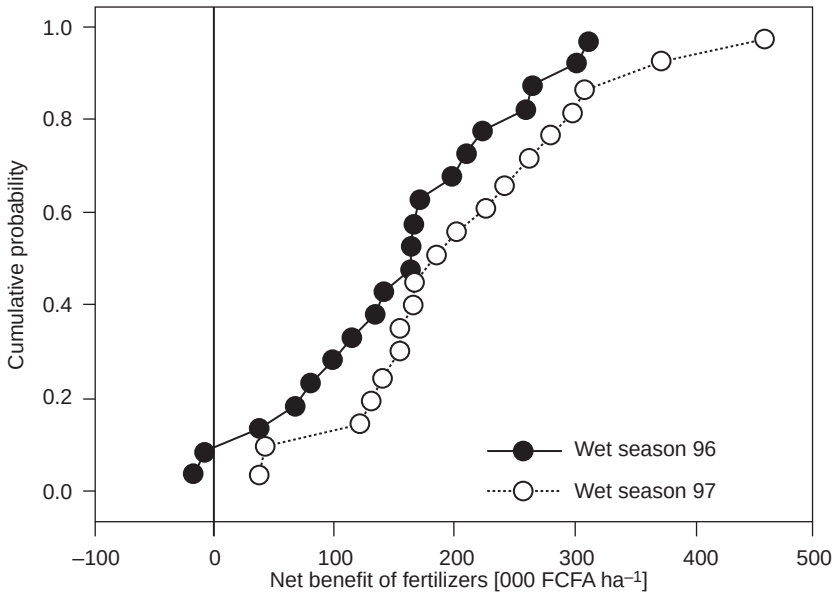


Fig. 3. Sample cumulative distribution functions of net returns to fertilizers for farmers in Guédé during the 1996 and 1997 wet seasons. On the horizontal axis is the net benefit received with fertilizer applications and, on the vertical axis, is the cumulative probability of having the corresponding level of returns or lower. Over the period of the presented surveys, the exchange rate was US$1.00 = 500FCFA (West African franc).

Farmers' perceptions

Farmers' main concerns at the end of the 1996 season (Figure 4) were (i) seed quality and supply, (ii) sale of paddy, and (iii) access to, and high cost of fertilizer. A few farmers also mentioned climatic constraints (hot, dry winds) as a cause of spikelet sterility problems in the dry season. In 1997, financial constraints (access

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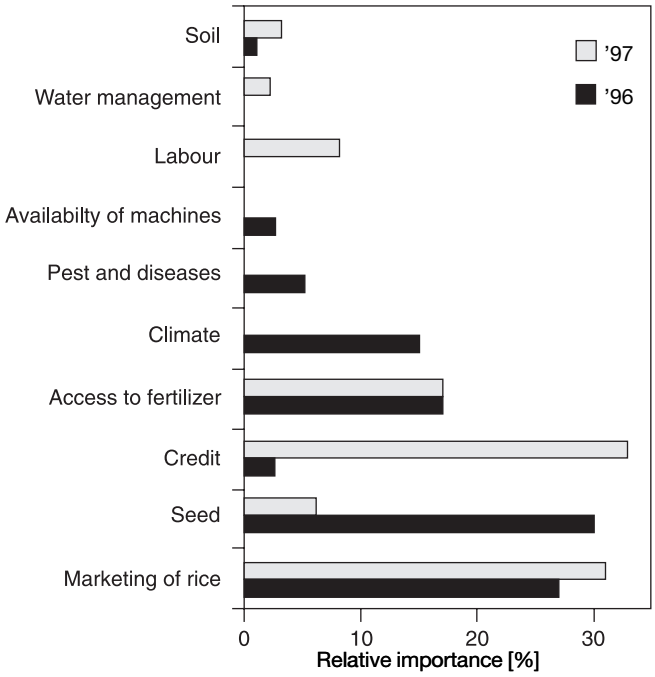


Fig. 4. Farmers' perceptions of major constraints in irrigated rice cropping in Guédé during the 1996 and 1997 wet seasons. Shown are average values for all farmers and all constraints mentioned.

to credit) were worrying farmers most, because of problems marketing paddy in the previous season. This also prevented rice crops being grown during the 1997 dry season. Marketing of paddy and access to and cost of fertilizer were among the top three constraints in both seasons (Figure 4). Seed supply was improved significantly during the 1997 wet season, with a third of the farmers using improved Sahel cultivars.

DISCUSSION

Pre-season surveys revealed a lack of farmers' knowledge on optimal timing and mode of fertilizer and herbicide application, optimal timing of drainage before harvest, and timing of harvest. Farmers' practices deviated from the 'optimal' cropping calendar as a result of this lack of information, and due to problems with access to credit, quality seed and fertilizer. Discussions among farmers, extension agents and researchers during the first season and before the onset of the second season resulted in integrated crop management recommendations, including timing of fertilizer and herbicide application, drainage and harvest. In spite of this information, timing of crop management operations was only slightly improved. Better-timed harvest might have reduced grain losses. The main improvements concerning fertilizer management were the adoption of a third N split application

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and the abandoning of a late second DAP application, which both improved synchronization of nutrient availability and plant needs at critical growth stages. As a result, recovery efficiency of N (REN) improved slightly. In the second season, the switch to newly released Sahel cultivars by almost half of the farmers resulted in a better uptake of indigenous soil N. Simulation of crop yield potential revealed more conducive weather conditions for rice cropping in 1997 with, on average, 0.5 t ha^{-1} higher potential yields. The average actual yield increase of 1.1 t ha^{-1} in 1997 can, therefore, be attributed to a better use of the indigenous soil N supply by the Sahel cultivars, a better synchronization of crop management interventions, especially timing of P and N fertilizer application, and more favourable weather conditions.

The yield gap between actual and potential yield ranged from 0 to 4.3 t ha^{-1} in both seasons, a much smaller range than reported by Wopereis *et al.* (1999) for other rice growing areas in the West African Sahel. Yields reported here are high compared with average yields reported by SAED (1998) for the Senegal River valley. One of the reasons may be that Guédé is a relatively old irrigation scheme, with experienced farmers.

Fertilizer N use was highly profitable in both seasons, with only two farmers having negative returns to fertilizer use in 1996 and with all farmers having positive returns to fertilizer use in 1997. Post-harvest surveys were instrumental in deriving farmers' perceptions of their major constraints. During the 1996 season, their main concerns were accessibility to quality seed and fertilizer, and marketing of paddy. During the 1997 season, the seed problem was partly solved with the introduction of the new Sahel cultivars. Because of difficulties in marketing the 1996–harvested product, however, they could not reimburse their debt in time and financial constraints became farmers' main concern in 1997.

The results reported here illustrate the multitude of factors influencing the performance of irrigated rice systems in the Sahel. Some available technologies or recommendations, such as optimal timing of fertilizer applications or timely harvest, are yet to be adopted by farmers. The authors' surveys revealed that farmer's knowledge of existing recommendations is imperfect, which partly explains the non-adoption of these technologies, and which shows the need for better dissemination of information. At the scheme level, the supply and the accessibility of agricultural inputs, such as quality seed and fertilizer need to be improved. To increase the competitiveness of locally produced rice *vis-à-vis* cheap imports, production costs per unit produced must be reduced or a higher quality product must be produced. There is a clear need to identify constraints and design solutions to speed-up technology transfer through collaborative assessment of existing technology, and training of key players in farmers' organizations, NGOs, and extension agencies. If farmers are given better access to information, rice technologies, inputs and decision making, rice production on irrigated land in West Africa may leap forward rapidly as potential production gains are still large.

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