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Rice farming in saline lowland of Sahel: Combination of anti-salt dam, salt-tolerant varieties, fertilizers to improve yields

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Salinity stress, drought and the lack of water supply are major constraints limiting rice productivity in rainfed lowland of the Sine Saloum region. To alleviate these constraints, several actions have been undertaken including construction of anti-salt dykes and using of salt tolerant varieties. The objectives of this study were: (a) analyze the hydraulic operation of these lowlands and salinity rate during wet season. (b) To test, the response of new salt-tolerant varieties, with different fertilizers and to identify the best suitable. Trials were conducted in two sites. The level of groundwater and salinity were measured during two wet seasons in two sites. At least 100 mm of rainfall are required to decrease salinity (EC) below 3 dS / m on a leveled land, before sowing. Before sowing, the management of water flow at the anti-salt dam must take into account not only the leaching of salt, but also the groundwater recharge. It is this groundwater that will allow rice to reach maturity, at the end of rains by mitigating late season drought. In both sites, *D14* and *IR70870-B-P-2-2* were the most biomass productive varieties. Among the eleven rice varieties tested, five have performed well with the average grain yields of 4 t.ha^{-1}.

Key words: Rainfall, groundwater, sea water, new salt-tolerant varieties, lowland.

INTRODUCTION

Rice is the most important food crop of the developing world and the staple food in the Sahelian nations of West Africa. Rice consumption in West Africa still increases, due to accelerating urban population growth and increasing levels of consumption per-capita (Seck et al., 2012). Senegal is one of the biggest rice importers in West Africa, (800,000 t per year) about 60% of local consumption (FAO-stat, 2012). Nevertheless, the part of imported rice can be reduced, by increasing local production, when considering the potential of various

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agro-ecological conditions in which rice can be produced (Lancon and Erenstein, 2002). In term of surface area, the rainfed lowland system is the most important reaching 60% of total rice-farming in Senegal (SAED, 2012). However, biophysical characteristics, rainfall hazard and water provision infrastructures determine the availability of water throughout the year (Kilian et al., 1999). Rice yields are generally low (Yoshida and Benta, 1983). Also, salt-stress, water deficiency and lack of best fertilizer management destabilize further more this fragile situation (Fukai et al., 1998; Diop et al., 2002). In Sine Saloum region, western Senegal, lowlands cover more than 500,000 ha, representing important resources for rural and national economy (Camara et al., 2007). Rice farming remains one of the main agricultural activities in this area (Mbodj, 2008). However, salinity stress caused by intrusion of sea water in these lowlands is the major constraint limiting rice-farming (Mbodj, 2001), (Camara et al., 2007). As consequence of land degradation, farmers are obliged to exploit upland areas, while the potential yield of the upland is lower than that of lowland (Yoshida and Benta, 1983), (DingKhun and Sow, 1997). In addition, water use efficiency on-farm is low, due to meantime and late season droughts, high evapotranspiration and failure of water control infrastructures (Tomar and Toole, 1980; Lilley and Fukai, 1994).

Rice crop suffers alternately from water excess and deficits, thus leaching and volatilization of nutrients are increased (Camara et al., 2008; Kaushal et al., 2009). Low water use efficiency illustrates the priority for improved water management in this region. To reduce the vulnerability of rice-farming activities, anti-salt dams have been built, in order to mitigate the salinity rate. Also, the using of salt-tolerant rice varieties gives opportunity to minimize salt effects and to produce higher yields than existing local varieties in this environment (Camara et al., 2008). It is in this context that Africa-Rice in collaboration with National Agricultural Research Station has just set up ten salt tolerant breeding lines for the Sahel Africa. In addition, best agricultural practices (e.g water control, management of fertilizer), contribute to reach that goal (WARDA, 2004). Therefore, the objectives of this paper were: (a) analyze the hydraulic operation of these lowlands and salinity rate during wet season in the presence of anti-salt dam. (b) To test, in these ecologies, the response of new salt-tolerant varieties with different types of fertilizers. (c) And to identify the best salt-tolerant varieties, suitable for saline lowland conditions in the Sahel.

MATERIALS AND METHODS

Experimental sites

Two field experiments were conducted during the wet season (from June to November 2011) in Ndour ndour (14°06'N, 16°18'W) and Nderderling (13°40'N, 16°24'W), located in Sine Saloum region, western Senegal. Sine Saloum region is located in Soudano Sahelian zone. Climate is characterized by a wet season, between 600 and 800 mm rainfall from June to October and a dry season from November to May. Average monthly maximum temperature is 39°C, reached between May-June. Average solar exposure is 9 h per day. Air humidity is high all year long (ANSD, 2009). In Ndour ndour, more than 50% of lowland areas are severely salt affected while Ndinderling site is moderately saline. Evaporation is very important about 2950 mm/year at Ndour ndour. Soil texture varies from sandy to clay sandy at both sites (Mankeur, 1999).

Anti-salt dikes

An anti-salt dam is a structure of water retention made in the valley of Sine Saloun to prevent the invasion of land by sea water and to protect and recover saline soils upstream of the structure. It includes a dike and evacuator regulated by a valve. The way of operation is described hereafter. At the beginning of the wet season, the valve remains closed to allow runoff to accumulate in the basin. Part of the retained water infiltrates and contributes to groundwater recharging. Salt accumulated in the soil dissolves in standing water. The valve is then opened to allow drainage of salt water. The capillary rise from the groundwater through layers of saline soil and its evaporation lead to accumulation of salt on soil surface. The valve is then closed to permit submersion again. Processes of submersion and drainage will continue until the threshold level of salinity (less than 3 dS/m) is obtained. At this time, land preparation is undertaken, followed by sowing or transplanting. At the end of wet season, the valve is closed to help keeping water in the lowland. This allows rice to reach maturity and also prevents capillarity rise of salt water.

Agronomic experiments

Trials were conducted during the wet season 2011 in the farmer fields at Ndinderling and Ndour Ndour sites. A factorial design was used with three replications, four fertilizer treatments as main plot, measuring 54 m^2 (27 m × 2 m) each and eleven rice varieties as sub plot, measuring 4 m^2 (2 m × 2 m) each. Direct sowing was done with three grains per hill, using inter-row distance of 20 cm and spacing of 20 cm within hills. Three fertilizers treatments were used (Table 1). For the first treatment, manure (3,000 kg ha^{-1}) was applied basally. For the second, mineral fertilizers used were urea (46% N), triple super phosphate (20% P), and potassium chloride (50% K). The third treatment was a combination of manure and mineral fertilizers.

Plant materials

The salt-tolerant breeding lines (Table 2) used in these trials were selected during the “Stress Tolerant Rice for Africa and South Asia” (STRASA) project, after a long screening process, in research station (Africa-Rice), and after experimentation in three countries (Gambia, Senegal, Mali) for tolerance to salinity. The screening program started with over 200 lines that were tested at 6 dS/m level of salinity, in the research station of Africa Rice in Ndiaye. After that screening, the salt-tolerant lines were selected and completed with many salt-tolerant lines from International Rice Research Institute (IRRI) which were screened also at 6 dS/m. The second step of this screening process took place in farmer’s fields in Senegal, Gambia and Mali between 2009 and 2010 during wet season.

Sampling, measurements and analyses

Three sub samples of top soil horizons (0 to 20 cm depth) were

Table 1. Description of fertilizer treatments used in the two experimental sites.

Fertilizers treatment (kg ha^{-1})	
MF: Mineral Fertilizer	90N-30P-30K
OF: Manure	3000 kg ha^{-1}
OMF: Manure and Mineral Fertilizer	3000 kg ha (OF)+ 90N-30P-30K (MF)
Control	No fertilizers

Table 2. Origins of the eleven rice varieties used.

Plant material	Origin
D14	IRRI
IR66946-3R-178-1-1	IRRI
WAS161-B-6-1	AfricaRice (Saint Louis)
IR70870-B-P-2-2	IRRI
IR67076-2R-15-3	IRRI
WAS197-B-8-2	AfricaRice (Saint Louis)
IKP	IRRI
SAHEL 236	AfricaRice
IR4630	IRRI
Sahel 201	Africa Rice
IR31785	IRRI

taken in the center of each plot. Sub samples were mixed thoroughly to get a composite sample, air dried and stored at 60°C for one week at laboratory. Analyses included pH_{H2O} on 1:2.5 extract and electrical conductivity (EC) on the 1:5 extract. Soil organic carbon was determined using the wet digestion method (Walkley et al., 1934). Available phosphorus was determined with the Bray 1 test (Bray and Kurtz., 1945). Groundwater's levels were measured using thirty piezometers at both sites. Electrical conductivities of standing water were checked, daily, using a portable conductivity meter during 2010 and 2011 wet season. Contour maps of salinity level at Ndour ndour and Ndinderling farms area were created using the Surfer 8.0 package before setting up the trial. For determination of dry biomass, three plants were harvested (cut flush to the ground) at the end of the vegetative growth stage. These samples are then passed in oven at 60°C for at least 3 days until complete dehydration. Then, the weight is measured with an electronic weight sensor. Grain yields were measured at 4 m^2 (2 m × 2 m). Analysis of variance (ANOVA) has been performed and the mean values have been compared using Student Newman Keuls (SNK) range test. Statistical procedures have been performed using the 9.1 version of SAS software (SAS Institute, 2004). Weather data were collected from stations near the experiment sites and the daily reference evapotranspiration (ETo) was estimated using Penman-Montieth method (Allen et al., 1998). Water use efficiency (WUE) on biomass basis has been calculated with respect to rainfall as follows:

$$WUE = \frac{BIOM}{\sum Rf}$$

BIOM: total above-ground biomass on dry weight basis; Rf: Rainfall during the cropping season.

RESULTS

Soil characteristics

Analyses of top soil horizon (0 to 20 cm) was done (Table 3). Soil in Ndour ndour was acidic with pH (H_2O) and pH (KCl) values of 4.74 and 4.46, respectively. In beginning of cropping season, the EC was already at 4.51 dS.m^{-1}, the P level was 8.33 mg.kg^{-1} (Bray 1) and the organic matter was 3.21%. While in Ndinderling, soil was slightly acidic with pH (H_2O) and pH (KCl) values of 6.19 and 5.11, respectively. EC was 0.54 dS.m^{-1}, P level was 8.59 mg.kg^{-1} (Bray 1) and organic matter was 4.0%. Intrusion of sea water in lowland has induced higher salinity in Ndour ndour compared to Ndinderling. The acidity could be explained by the nature of soils, and chemical reactions between iron transported by water drained from the continent and sea water (Maryse, 1991). However, the soil organic matter was relatively high at both sites, probably due to alluvial and colluvial deposits of organic sediments in the bed of the stream (Perez, 1994).

Evolution of salinity in relation of rainfall

In Figure 1, the salinity in the lowland falls under 3 dS/m after 103.5 mm of rainfall in June 2010 ending. In 2011, after 150 mm of cumulative rainfalls, reached on 30th of July, the salinity was approximately 2 dS/m. This shows that at least 100 mm of rainfall is required for enough leaching of salt in order to reach the threshold of 3 dS/m before sowing. As seen in the contour map (Figures 2 and 3), salinity is not uniform, because leaching also is not uniform due to the fact that terrain is not levelled.

Rain, groundwater, salinity dynamics and their impacts on rice growth

Ndour Ndour: Rice roots are in 90% located in 0 to 30 cm depth. So long as the level of the groundwater is less than 30 cm, it hardly contributes to the rice water supply. In this lowland, the groundwater table, despite of a gradual recharge, was less than 50 cm (Figure 4) during the seed germination and young seedlings growth. However, more than 80% of rains occurred during this period. This allowed having relatively high moisture in the

Table 3. Main characteristics of top soil horizon.

Parameter	Ndour Ndour	Ndinderling
pH (H_2O)	4.74	6.19
pH (KCl)	4.46	5.11
EC ($dS.m^{-1}$)	4.51	0.54
C (%)	1.87	2.34
MO (%)	3.21	4.03
P Bray 1 ($mg.kg^{-1}$)	8.33	8.59

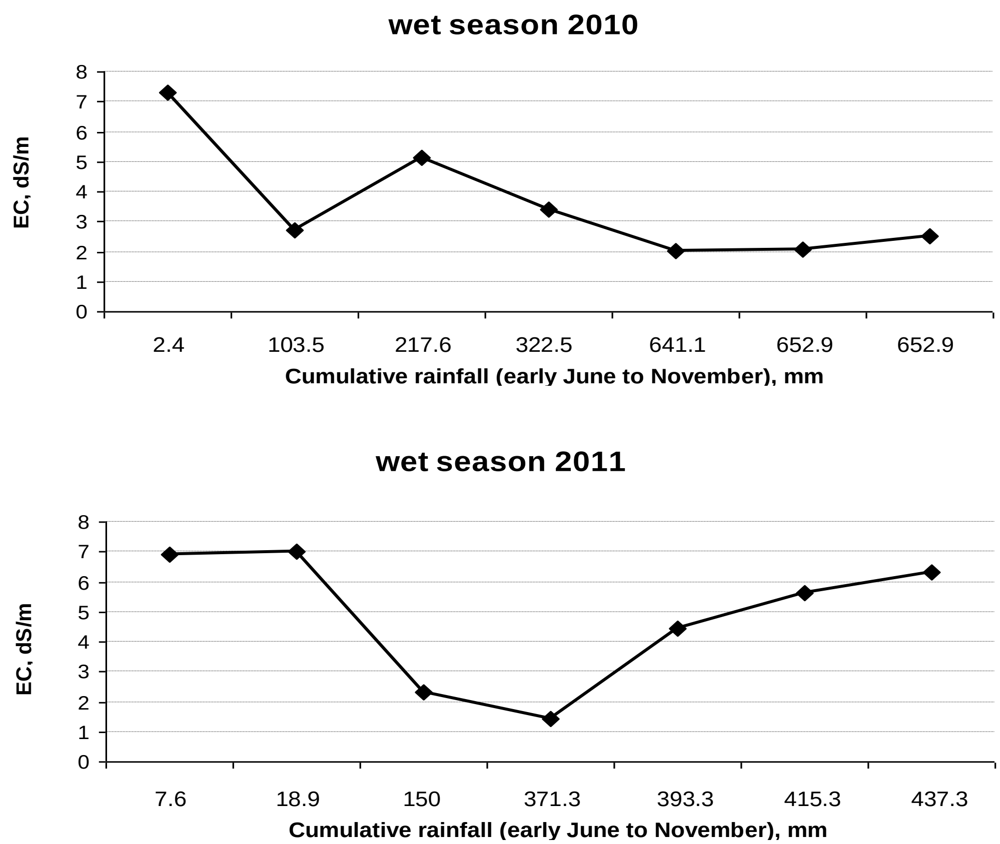

Figure 1. Evolution of mean salinity in the lowland of Ndour Ndour, versus cumulated rainfalls during the wet season 2010 and 2011.

soil. First rains have also allowed leaching of salt thanks to anti-salt dam. Water stress was not very pronounced during the end of vegetative growth at the beginning of the reproductive phase (Figure 4). Rains having stopped in October, this has resulted in a decrease in groundwater table (Figure 4). During the end of the reproductive phase, at maturity, soil moisture was near the permanent wilting point.

As shown in the salinity map of Ndour Ndour (Figure 2), average salinity was lower than 3 dS/m of sowing day. From early June to late August (Figure 1: wet season 2011) lowland has received a significant quantity of rain: 371.3 mm which helped to lower the salt level (Figure 1, wet season 2011).

This decrease is also emphasized by Figure 5. On the opposite, after the end of August, the decline in rainfall has resulted in an increased level of salt. This increase in salinity (Figure 5) is due to the lack of standing water (Figure 4) to prevent salt accumulation coming up from the ground via capillarity and remaining after evaporation.

Ndinderling: Given that the salinity was below the threshold during sowing (Figure 3), the valve stayed closed. That led to keeping water for long time and

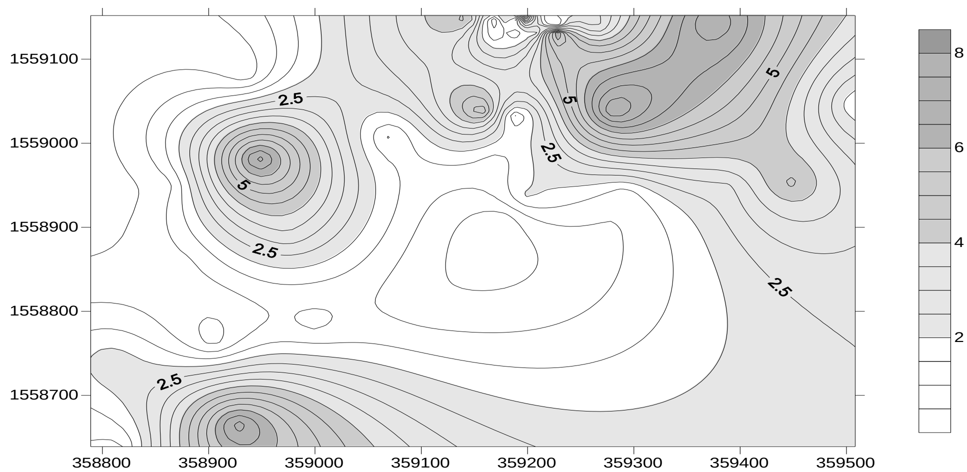

Figure 2. Contour of spatial variability of electrical conductivity (dS.m^{-1}) in the early wet season 2011 at Ndour Ndour before sowing in 28 ha area (x scale: 1.0 inche = 119.865 m, y scale: 1.0 inche = 119.865).

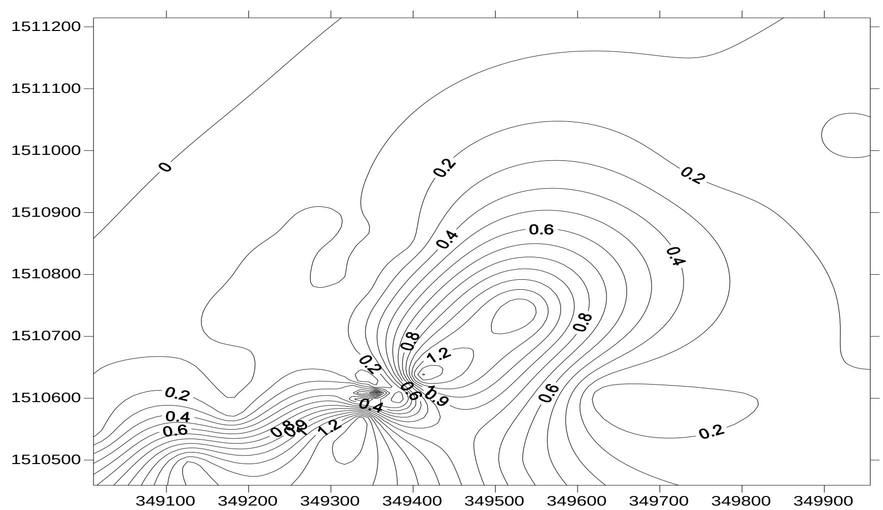

Figure 3. Contour of spatial variability of electrical conductivity (dS/m) in the early wet season 2011 at Ndinderling before sowing in 56 ha area (x scale: 1.0 inche = 157.42 m, y scale: 1.0 inche = 157.42).

permitted its infiltration and deep leaching of salt. Indeed, standing water has achieved the height of 100 cm at surface between September and October. At this stage the main issue is the risk of submersion: At least, one of the leaves should stay out of water for respiration purpose. From October to December, water table decreased from 100 cm to -20 cm (Figure 6). The abundance of rainfall (Figure 6) and the permanent standing water have allowed a continuous leaching of salt and the dilution of the concentration. This has resulted in a low rate of salinity throughout the crop cycle (Figure 7).
Crops have used water of the groundwater table after the end of the rains in October. In Ndinderling, rainfall of 758 mm exceeded ETo (554 mm). Finally, there was no salt stress or rainfall deficit during the trial in the lowland of Ndinderling, allowing subsequently, each variety to reach maturity.

Biomass and grain yields

Ndour Ndour: Biomass production was significantly influenced by the type of fertilizer and the different varieties used, but no interaction was observed between the type of fertilizer and variety (Table 4). The average biomass produced was 4.68 tha^{-1} and the control, OF,

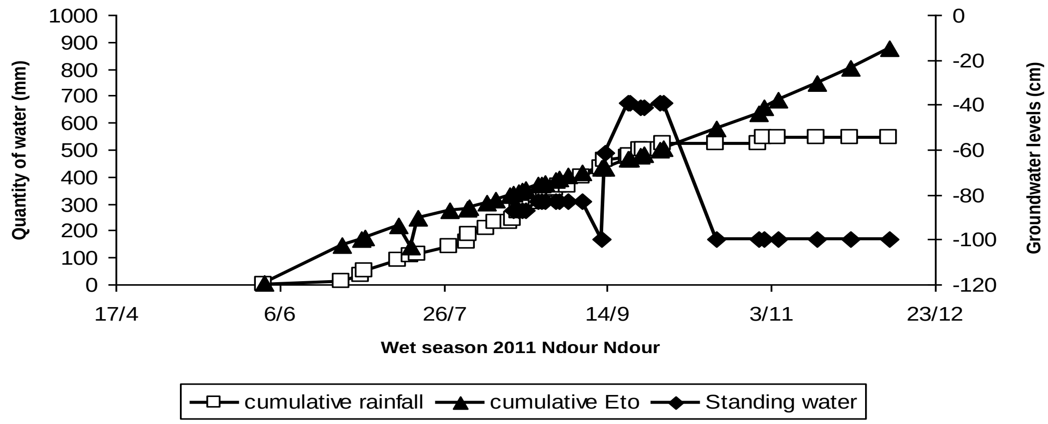

Figure 4. Variation of the rainfall, reference evapotranspiration (ETo) and groundwater table during the wet cropping season from June to December 2011 in Ndour Ndour.

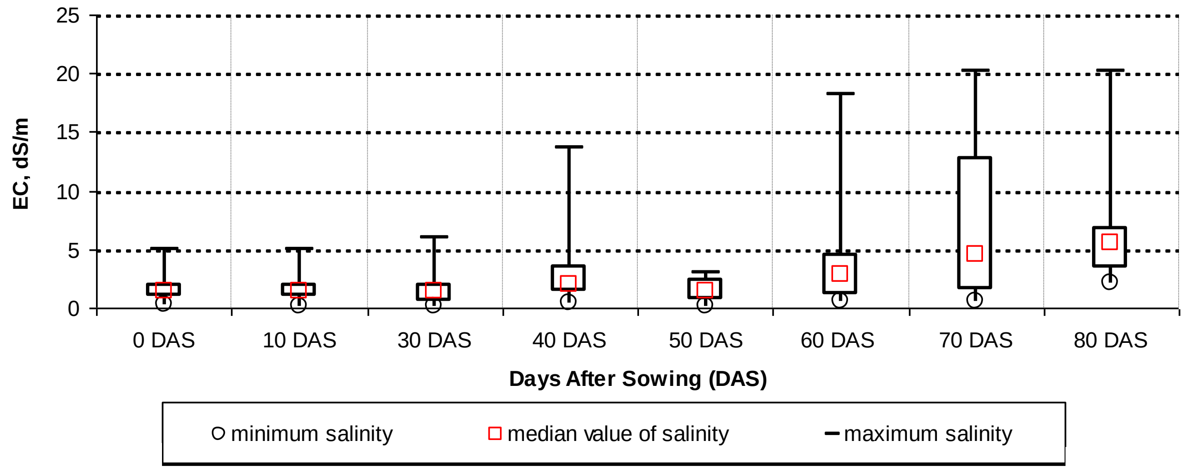

Figure 5. Trend of electrical conductivity (EC) during 80 days after seedling in Ndour Ndour.

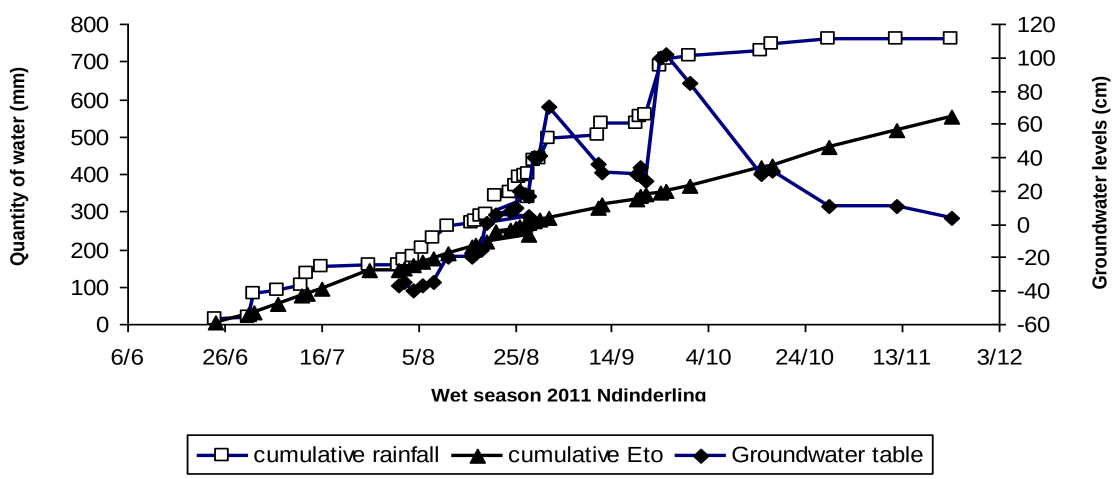

Figure 6. Variation of rainfall, reference evapotranspiration (ETo) and groundwater table during the wet cropping season from June to December 2011 in Ndinderling.

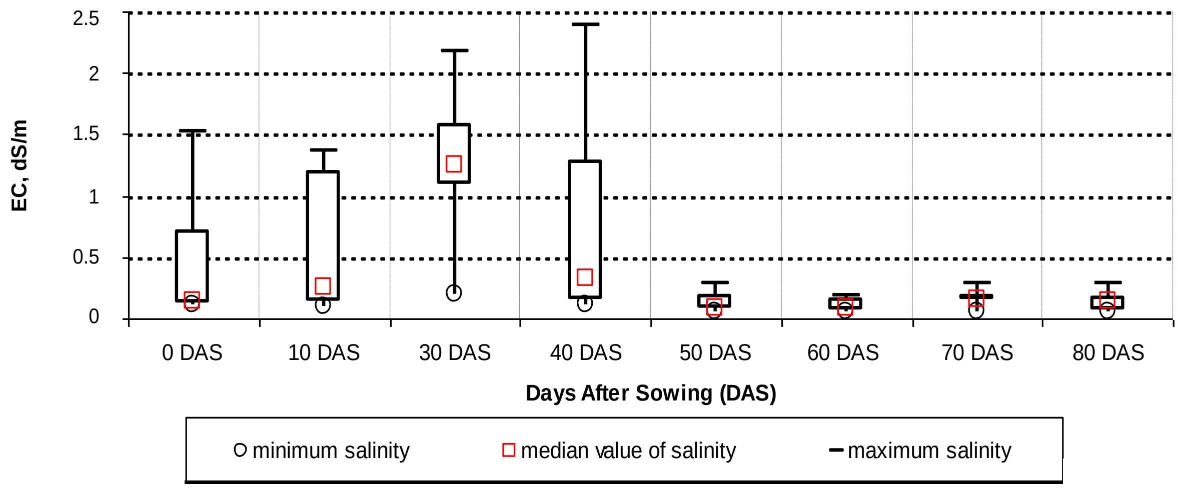

Figure 7. Trend of electrical conductivity (EC) during 80 days after seedling in Ndinderling.

Table 4. Analysis of the variance of the effects of fertilizer treatments, varieties, sites, and interactions within factors on rice biomass production.

Source		DF	Mean square	F Value	Pr > F
Fertilizer		3	202.4307435	25.83	0.0001
Variety		10	20.7133373	2.64	0.0059
Site		1	512.0516156	65.34	0.0001
Treatment*Variety		30	7.165653	0.91	0.5982
Treatment*Site		3	2.2452228	0.29	0.8351
Variety*Site		10	6.4760474	0.83	0.6040
Treatment*Variety*Site		30	8.203849	1.05	0.4136
R-Square	0.683426				
Coeff Var	49.72243				

MF and OMF gave respectively 2.01, 3.7, 6.14, and 6.89 t.ha^{-1}. *D14*, *IR4630* and *IR70870-B-P-2-2* were the most productive varieties, respectively 5.52, 5.37 and 5.19 t.ha^{-1}; the sensitive check *IR31785* produced 3.21 t.ha^{-1}(Table 5).

Ndinderling: Biomass production was significantly influenced by the type of fertilizer and the different varieties used, but no interaction was observed between the type of fertilizer and variety (Table 4). The average biomass was 7.79 t.ha^{-1} and the control, OF, MF, and OMF gave respectively 4.53, 6.94, 8.88, and 10.81 t.ha^{-1}. *Sahel 236*, *D14* and *IR70870-B-P-2-2* varieties were the most productive respectively 9.67, 9.10 and 8.92 t.ha^{-1}. The sensitive check *IR31785* produced 4.26 t.ha^{-1} (Table 5). *D14*, *WAS161-B-6-1*, *Sahel 236*, *Sahel 201* and *IR4630* varieties have performed well; they can produce up to 4 t.ha^{-1} grain yield in a salt water environment (Figure 8) higher than average yield obtained by farmers in this region (1.5 t.ha^{-1}) (Mbodj, 2008). Thus, this can provide better alternatives for farmers.

Water use efficiency (WUE)

Ndour Ndour: WUE was significantly influenced by the type of fertilizer and the variety. Difference between tolerant varieties and the sensitive variety was significant (P < 0.05), however no significant difference within tolerant varieties was observed (P < 0.05). Average WUE of sensitive variety (IR 31785) was 0.59 kg.m^{-3} and among the tolerant varieties, D14 gave the greater WUE (1.01 kg.m^{-}3). Average WUE was 0.37; 0.68; 1.12 and 1.26 kg.m^{-3} respectively under control, OF, MF and OMF (Table 6). As comparison to control, OF and MF, average WUE under OMF was increased by 71, 46 and 11%, respectively.

Ndinderling: WUE was significantly influenced by the type of fertilizer and the variety. Difference between tolerant varieties and the sensitive variety was significant (P < 0.05); however no significant difference within tolerant varieties was observed (P < 0.05). Average WUE

Table 5. Effects of fertilizer treatments on above-ground biomass production ($t.ha^{-1}$).

Rice cultivar	Ndour Ndour					Ndinderling				
	Ctrl	OF	MF	OMF	Mean	Ctrl	OF	MF	OMF	Mean
D14	2.20	4.93	6.63	8.31	5.52[a]	4.99	7.90	9.58	13.93	9.10[a]
IR66946-3R-178-1-1	2.74	2.49	6.39	7.47	4.77[ab]	3.98	6.62	9.31	11.02	7.73[ab]
WAS161-B-6-1	1.30	3.90	5.66	5.95	4.20[ab]	5.19	5.13	10.48	9.62	7.60[ab]
IR70870-B-P-2-2	1.82	4.11	8.90	5.92	5.19[a]	4.95	9.40	10.13	11.18	8.92[a]
IR67076-2R-15-3	1.93	3.64	6.71	6.73	4.75[ab]	5.19	7.10	9.81	10.05	8.04[ab]
WAS197-B-8-2	2.22	4.33	5.92	6.42	4.72[ab]	4.55	5.67	7.82	10.09	7.03[ab]
IKP	1.27	3.52	4.83	7.03	4.16[ab]	4.47	6.01	6.50	8.85	6.46[ab]
Sahel 236	3.10	3.00	6.37	7.13	4.90[ab]	4.78	8.40	11.08	14.40	9.67[a]
IR4630	1.62	4.52	6.99	8.35	5.37[a]	3.80	8.48	9.32	12.56	8.54[ab]
Sahel 201	2.27	4.56	4.72	7.30	4.71[ab]	4.98	7.44	9.22	11.79	8.36[ab]
IR31785	1.58	1.73	4.37	5.13	3.21[b]	3.00	4.23	4.40	5.40	4.26[b]
Mean	2.01[b]	3.70[b]	6.14[a]	6.89[a]		4.53[b]	6.94[b]	8.88[ab]	10.81[a]	

Mean with the same letters are not significantly different by Student Newman Keuls test at the 0.05 level.

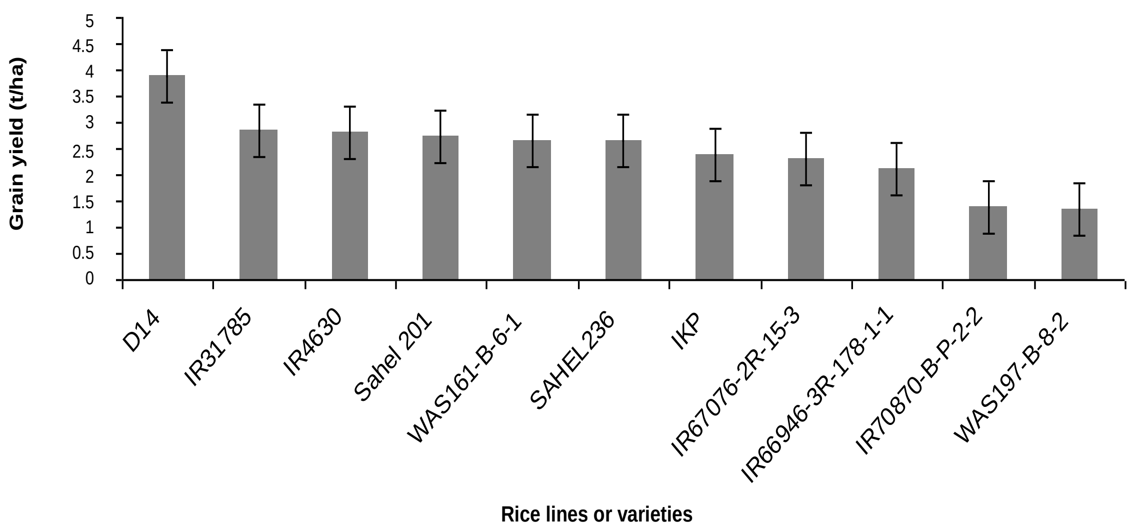

Figure 8. Average grain yields of the eleven rice varieties in moderate saline condition of Ndinderling with statistical range equal 1.3 t/ha.

of sensitive variety (*IR 31785*) was 0.56 $kg.m^{-3}$ and among the tolerant varieties, *Sahel 236* gave the greater WUE (1.28 $kg.m^{-3}$). Average WUE was 0.60, 0.92, 1.17, and 1.43 $kg.m^{-3}$ under control, OF, MF and OMF (Table 6). As comparison to control, OF and MF, average WUE under OMF was increased by 58, 36 and 18% respectively.

DISCUSSION

In these lowlands degraded by salt, there should be a gap between the beginning of the rainy season and planting date. In fact, the sowing should intervene after the lowlands have received rainfall of at least 100 mm. This is much enough to leach the salt that has been accumulated during the dry season under 3 dS/m which is tolerable for rice. In these lowlands, rice water need must therefore take into account that quantity needed for the leaching of salt. As the map of salinity (Figure 2) shows, the levelling is an essential element for the proper salt leaching. The lowlands must have a low slope (eg0.1%) descending toward the anti-salt dam. Once the valve is closed there will be a uniform height of water throughout the lowland and saline water can be evacuated. Good leaching allows uniform salinity. Salinity higher than 3 dS/m will have no effect on the germination

Table 6. Effects of fertilizer treatments on the water use efficiency (WUE in kg.m^{-3}).

Rice cultivars	Ndour ndour					Ndinderling				
	Ctrl	OF	MF	OMF	Mean	Ctrl	OF	MF	OMF	Mean
D14	0.40	0.90	1.21	1.52	1.01 [a]	0.66	1.04	1.26	1.84	1.20[a]
IR66946-3R-178-1-1	0.50	0.46	1.17	1.37	0.87[a]	0.53	0.87	1.23	1.45	1.02[a]
WAS161-B-6-1	0.24	0.71	1.03	1.09	0.77[a]	0.68	0.68	1.38	1.27	1.00[a]
IR70870-B-P-2-2	0.33	0.75	1.63	1.08	0.95[a]	0.65	1.24	1.34	1.48	1.18[a]
IR67076-2R-15-3	0.35	0.66	1.23	1.23	0.87[a]	0.68	0.94	1.30	1.33	1.06[a]
WAS197-B-8-2	0.41	0.79	1.08	1.17	0.86[a]	0.60	0.75	1.03	1.33	0.93[a]
IKP	0.23	0.64	0.88	1.29	0.76[a]	0.59	0.79	0.86	1.17	0.85[a]
Sahel 236	0.57	0.55	1.16	1.30	0.90[a]	0.63	1.11	1.46	1.90	1.28[a]
IR4630	0.30	0.83	1.28	1.53	0.98[a]	0.50	1.12	1.23	1.66	1.13[a]
Sahel 201	0.42	0.83	0.86	1.34	0.86[a]	0.66	0.98	1.22	1.56	1.10[a]
IR31785	0.29	0.32	0.80	0.94	0.59[b]	0.40	0.56	0.58	0.71	0.56[b]
Mean	0.37[b]	0.68[b]	1.12 [a]	1.26 [a]		0.60[b]	0.92[ab]	1.17[ab]	1.43[a]	

Mean with the same letters are not significantly different by Student Newman Keuls test at the 0.05 level.

Table 7. Average young seedling survival rate (YSSR) in saline soil of Ndour Ndour.

Rice varieties	Average YSSR (%)
D14	82[a]
WAS161-B-6-1	80[a]
WAS197-B-8-2	81[a]
IR66946-3R-178-1-1	74[a]
IR70870-B-P-2-2	78[a]
IR67076-2R-15-3	79[a]
IR4630	83[a]
IKP	85[a]
Sahel 236	80[a]
Sahel 201	85[a]
IR31785	58[b]

Values with the same letter are not significantly different by Student Newman Keuls test at the 0.05 level.

rate but will result in death of seedlings. Soil moisture was not used by the seedlings where the salinity exceeds 6 dS.m^{-1} because its increase osmotic potential and the varieties used have been selected at 6 dS/m. Indeed, at -2.34 MPa (osmotic potential = -039EC) (Chinnusamy et al., 2005), which is less than -1.5 MPa (soil water potential at permanent wilting point) (Chinnusamy et al., 2005) led to the death of many young seedlings (Table 7).

Indeed, the young seedlings were very sensitive to salinity (Zeng et al., 2000). At this, salt stress is added to hydric stress at the lowland Ndour Ndour. The effects of drought on yield are most severe when paddies are stressed by water deficit in the pre-flowering stage (Tsubo et al., 2006). The rainfall deficit versus the rice need for water was 18.3%. That does not include the losses of water due to lateral and downward movement (Tsubo et al., 2006). The impact of water deficit on rice is much accentuated in saline soils. As consequences, rice survival rate after seedling was decreased approximately by 20% with tolerant varieties and by 42% with sensitive variety (Table 7), and the number of tiller per plant was decreased by 25%, in Ndour ndour compared to Ndinderling (Table 8). This sensitivity of rice to salinity and water deficit stresses have been emphasized by some authors as (Tsubo et al., 2006; Walia et al., 2005; Tabbal et al., 2002; Ceuppens et al., 1997).

This lower rate of tillering at Ndour Ndour, compared to Ndinderling has affected biomass. Biomass production was greater in Ndinderling compared to Ndour ndour. At both sites, the OMF gave the best above-ground biomass. In fact, this combination increases the capacity of nutrient reserves and makes easy the availability of nutrients to plants (Craswell and Lefroy., 2001; Bado et al., 1997; Bationo and Mokwunye, 1991).

However, because of the relatively high organic matter at both sites, only application of MF gave also greater above-ground biomass compare to OF and the control treatments. Low rainfall, after August was not sufficient to prevent the capillary rise of water from the salt water which led to the high salinity at the end of the season at Ndour Ndour and resulted in the spikelets sterility. Nevertheless, at Ndinderling site, the sensitive check *IR31785* produced 4.26 t.ha^{-1}. *D14*, *WAS161-B-6-1*, *Sahel 236*, *Sahel 201* and *IR4630* varieties have performed well; they can produce up to 4 t.ha^{-1} grain yield in a salt water environment, higher than average yield obtained by farmers in this region (1.5 t.ha^{-1}) (Mbodj, 2008). Thus, this can provide better alternatives for farmers.

Significant yield and WUE increase can be expected by using both organic and mineral fertilizers and more water supplies. Moreover, WUE in Ndour ndour was lower

Table 8. Average number of tillers per plant.

Rice varieties	Ndour ndour	Ndinderling
D14	21[a]	24[a]
WAS161-B-6-1	18[a]	26[a]
WAS197-B-8-2	22[a]	26[a]
IR66946-3R-178-1-1	18[a]	21[a]
IR70870-B-P-2-2	19[a]	24[a]
IR67076-2R-15-3	20[a]	22[a]
IR4630	20[a]	26[a]
IKP	17[a]	22[a]
Sahel 236	20[a]	25[a]
Sahel 201	19[a]	22[a]
IR31785	13[b]	23[a]

Values with the same letter per column are not significantly different by Student Newman Keuls test at the 0.05 level.

than Ndinderling, respectively 0.86 and 1.03 kg.m^{-3} in average.

Conclusion

Sowing at these salt lowlands must occur after a rainfall of at least 100 mm. This amount of water should be integrated into the rice water need. However, levelling the lowlands allows a uniform leaching. After sowing, the management of water flow at the anti-salt dam must take into account, not only leaching of salt, but also groundwater recharge. Indeed, it is this groundwater table that will allow rice to reach maturity at the end of rains in the rainfed lowlands, by mitigating late season drought on the one hand. On the other hand, this infiltration will reduce the salinity of water. Biomass production was greater in Ndinderling compared to Ndour ndour. In both sites, *D14* and *IR70870-B-P-2-2* were the most biomass productive varieties, respectively 5.52, 5.19 t.ha^{-1} in Ndour Ndour; and 9.10 and 8.92 t.ha^{-1} in Ndinderling. At both sites, OMF gave the best above-ground biomass. Because this combination increases the capacity of nutrient reserves and makes easy the availability of nutrients to plants. Among the eleven rice varieties tested, five have performed well: *D14*, *WAS161-B-6-1*, *Sahel 236*, *Sahel 201* and *IR4630*, with greater average grain yields of 4 t.ha^{-1} compared to the 1.5 t.ha^{-1} obtained by farmers. Significant yield and WUE increase can be expected by using both organic and mineral fertilizers and more water supplies. Results of this study provided useful information for integrated management of tolerant rice varieties, water control and fertilizers in the rainfed lowland rice. As perspective to improve this system, using of high yielding tolerant rice varieties associated with organic and mineral fertilizers and additional irrigation source can help to recover the abandoned land and improve rice productivity in this region.

Conflict of Interest

The authors have not declared any conflict of interest.

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