Yield Responses of Irrigated Rice to Salinity

depend on development stage and stress level

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Introduction

Irrigated rice (*Oryza sativa* L.) is grown on about 45,000 ha in the Senegal River Delta in both Mauritania and Senegal. Soils are naturally saline in this area due to the shallow water table with salinity levels ranging from 20 to 100 mS cm^{-1}. Rice cropping can reduce soil salinity by blocking capillary rise of salts due to a ponded water. However, salinity levels at the onset of both wet and dry season can still reach relatively high levels, because of the absence of the ponded water layer between seasons and at harvest. Therefore, rice cultivars are needed that can resist varying levels of soil salinity at critical growth stages of the rice plant. Salinity affects germination, crop establishment, dry matter production and leaf area development, seed set rate, and sterility. The severity of these effects depends on several factors: (i) the intensity of the stress, (ii) the climatic conditions, (iii) the resistance level of the genotype. The objectives of this study were to (i) illustrate varietal responses to seasonal salinity in the two major growing seasons of the Senegal River Delta and (ii) derive rules of thumb for surface water drainage at critical levels of salinity for particular growth stages of the crop.

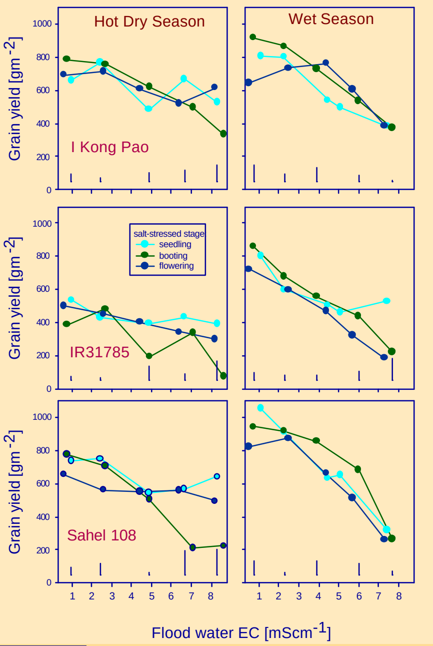

Figure 1 Grain yield at maturity of three field grown rice varieties for the two 1998 cropping seasons in Ndiaye, Senegal, at 5 different levels of salt stress. EC = electrical conductivity. Error bars = LSD between treatments at a given EC, p<0.05.

Grain yield was generally reduced by salinity levels with EC > 2 mS cm^{-1}.

Results

Floodwater salinity was applied at early seedling stage, one week before and after panicle initiation (booting), or one week before and after flowering.

Salinity

- Salinity effects were most severe when applied during the reproductive stages.
- Yields declined by about 0.6 - 1 t ha^{-1} per unit EC for EC levels > 2 mS cm^{-1}.
- Salinity effects on spikelet sterility differed among varieties.

Season

- In the HDS, yield reductions were least severe if the stress was applied at the seedling stage and most severe if the stress occurred around PI. In the WS, yield decline with EC was similar for all three development stages at which stress occurred.

Genotype

- In tolerant I Kong Pao no increase in sterility was observed.
- Moderately tolerant Sahel108 showed an increase in sterility when stressed during the booting stage in the HDS at EC levels > 5 mS cm^{-1}, and in the WS when stressed during flowering at EC levels > 6 mS cm^{-1}.
- In susceptible IR31785, salinity generally increased sterility. Effects were most severe in the HDS and when stressed during the reproductive stages.

Materials and Methods

All experiments were conducted at the research farm of the West Africa Rice Development Association (WARDA) in Ndiaye, Senegal (16°14'N, 16°14'W). Climate data were recorded automatically next to the experimental plots. 3 rice varieties, commonly grown in the region were directly seeded on 27.02.1998 for the HDS trial and 26.08.98 for the WS trial. (I) I Kong Pao, tropical japonica landrace, traditional , salt tolerant, (II) Sahel108, also known as IR13240-108-2-3-3, indica-type, high yielding improved semi-dwarf, moderately salt tolerant and (III) IR31785-58-1-2-3-3 (henceforth IR31785), indica-type, high yielding, improved semi-dwarf, salt susceptible. Salinity treatments were applied at three different development stages. (1) at seedling stage (14 d), (2) around panicle initiation (14d, starting 7 days before panicle initiation up to 7 days after panicle initiation), and (3) around flowering (14 d, starting 7 days before flowering up to 7 days after flowering). At all other times, plots were irrigated with fresh irrigation water. Electric conductivity (EC) of the irrigation water was used as a proxy for salinity. Treatments were 0-1 mScm^{-1} (control, normal irrigation source), 2 mS cm^{-1}, 4 mS cm^{-1}, 6 mS cm^{-1}, and 8 mS cm^{-1}. Plot size was 2.25 m^2 per variety, replication and treatment.

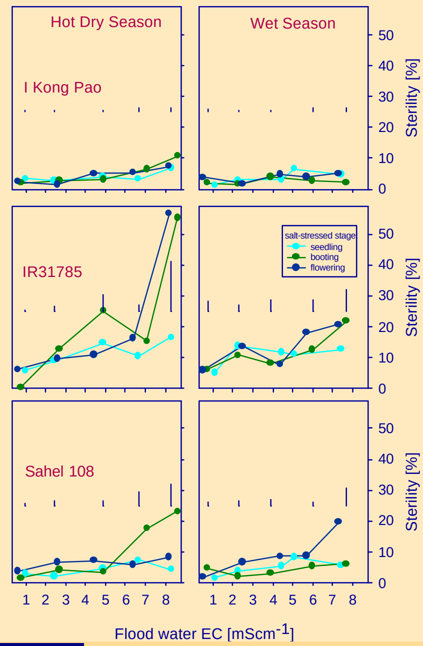

Figure 2 Spikelet sterility of three field grown rice varieties for the two 1998 cropping seasons in Ndiaye, Senegal, at 5 different levels of salt stress. EC = electrical conductivity. Error bars = LSD between treatments at a given EC, p<0.05.

Salinity effects on sterility differed strongly among varieties and seasons.

Discussion

Surprisingly, yield reductions due to salinity were more severe in the wet season (WS) than in the hot dry season (HDS). Low air hum-idity increases salt uptake to the plant and enhances salinity stress. In the wet season, air humidity values are normally relatively high, reducing the transpi-rational volume flow and thus salt uptake to the plant. Figure 3 compares annual time courses for the present study with those for a period of five years. 1998 was an extremely dry year, even for the Sahel. We chose a relatively late sowing date for the WS trial, because of time con-straints between the two seasons. The reproductive stage of the crop fell, therefore, into an unusually dry air humidity environment, which explains the strong salinity effects on the crop.

In cases where seasonal salinity can not be avoided, a short duration crop should be sown about a month earlier in the WS to avoid additional atmospheric stresses. Decisions when to drain saline surface water depend, therefore, not only on salinity levels and the crops development stage, but also on atmospheric conditions.

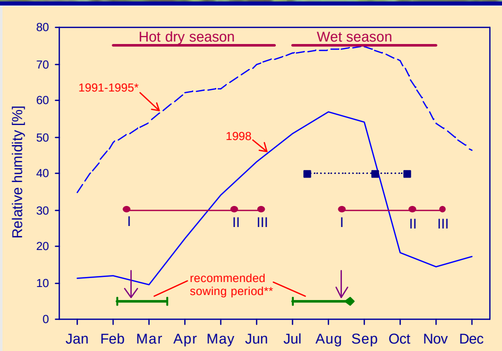

Figure 3 Profile of air humidity for 1991-1995 (monthly median across 5 years) and 1998. Seasons, indicated as practiced in the region by red horizontal lines in the top. Diamonds = recommended sowing periods. Circles = duration to maturity, Sahel108, 1998. (I) sowing, (II) 50% flowering, (III) maturity. Squares = recommended sowing and estimated duration for a hypothetical wet season cultivar grown under seasonal salinity.

Risk of atmospheric drought should be avoided at early reproductive stages of rice grown under saline conditions.

Conclusions

- Salt stress reduced rice yield regardless of stress level, timing of stress occurrence, and season.
- In farmers' fields that have some inherent salinity, critical levels need to be defined to trigger counteractive measures.
- Values of floodwater EC < 2 mS cm^{-1} can be tolerated.
- Floodwater EC levels > 2 mS cm^{-1} may lead to losses of up to 1t ha^{-1} per unit EC.
- Early reproductive stages, i.e. panicle initiation and booting were more affected by salinity than flowering or seedling stage.
- Early sowing, use of salt tolerant cultivars, and drainage during sensitive growth stages if floodwater EC > 2 mS cm^{-1} may improve farmers' output from rice fields in the Senegal River Delta.

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