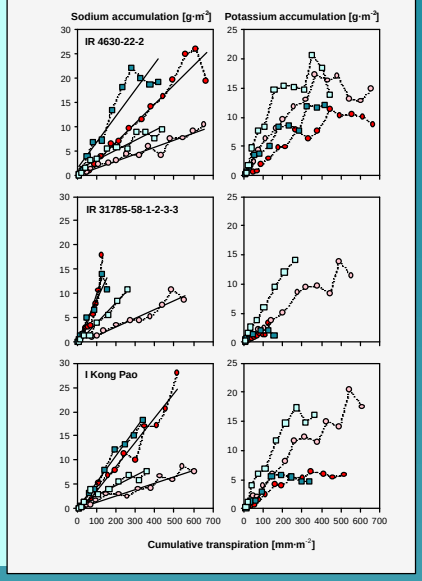
Effects of Transpiration on Sodium and Potassium Distribution in Salt Stressed Irrigated Rice

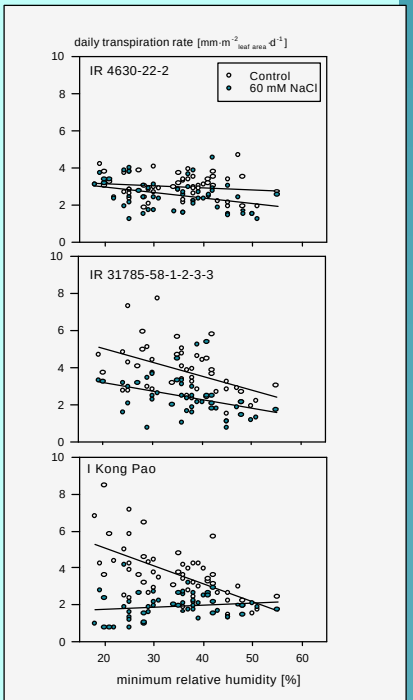
F. Asch[1], M. Dingkuhn[2], K. Dörffling[1]

1) Institute for General Botany, University of Hamburg, Ohnhorststr. 18, 22609 Hamburg, Germany
2) West Africa Rice Development Association (WARDA), Bouake, Ivory Coast



ig. 1 of simulated cumulative transpiration in saline and non-saline ils. (Field trial, hot dry season and wet season 1994; simulations with RYZA_W model, measured LAI as input. Blue = wet season; red = hot y season; dark shades = salinity treatment; light shades = control.

Na uptake is transpiration driven but depends on genotype and salt level



ig. 2 Varietal differences in measured daily transpiration rates (Tr as a function of minimum relative humidity (RH) under saline nd non-saline conditions. TR and leaf area (LA) were measured over eason. TR is expressed on LA basis. (screenhouse trial, wet season 994. Upper regression line = freshwater treatment, lower regression he = salt treatment. 60mM NaCl in the culture solution).

Reactions of stomata to salt depend on genotype and RH

Introduction

Soil salinity is a major constraint to irrigated rice production in the Sahelian region of sub-Saharan Africa. Strong climatic differences between the two major cropping seasons render the varietal salt tolerance evaluation difficult. Screening results from humid Asian environments were often not transferable to Sahelian dry season conditions. Varietal differences in Na and K uptake and distribution in irrigated rice were studied in the delta of the Senegal river, Senegal (200-400mm rainfall/yr), through field and screenhouse experiments (saline/non-saline conditions; three varieties; wet/dry season) and Phytotron experiments at the University of Hamburg, Germany. Questions addressed: (1) is Na and K uptake transpiration driven? (2) does stomatal regulation of transpiration contribute to salt tolerance? (3) is Na uptake modulated by a "root filter"? (4) is Na retained in the stems (leaf sheaths)?

Results

Responses to salinity were studied for 3 varieties. I Kong Pao (IKP), short duration, tolerant; IR4630-22-2 (IR4630), medium duration, tolerant, and IR31785-58-1-2-3-3 (IR31785), short duration, susceptible.

Potential canopy transpiration was simulated for each variety, using the evapotranspiration routine of ORYZA_W with measured LAI and meteo data as input. The cumulative canopy transpiration per ground area over the season was calculated and the observed cumulative Na and K uptake was plotted against it (**Fig.1**). Na accumulation was proportional to the cumulative transpiration in both seasons, but K uptake was not; Na uptake rate per unit of water transpired, however, depended on variety and treatment and season, where as seasonal influence on K uptake was low.

The transpiration data of Fig.1 were based on simulation; neither salt treatment nor air humidity (RH) specific effects on stomata were accounted for. To determine RH x salinity effects on transpiration, daily transpiration rates (TR) and leaf area (LA) were measured over a season on plants grown in Yoshida culture solution. TR were expressed on LA basis (**Fig.2**). TR of IR4630 were generally low, and not influenced by RH or salt treatment. In IKP, TR markedly increased with decreasing RH under control conditions, but did not respond under salinity. For IR31785, TR increased with decreasing RH under both saline and control treatments, although TR were lower under salinity. It appears, that tolerant check IR4630 generally controlled its transpiration, IKP specifically under salinity, and susceptible check IR31785 controlled its transpiration least.

In order to estimate how much Na will get into the shoot at a given outside salinity, root xylem Na concentrations were compared with culture solution Na concentration in a phytotron study (**Fig. 3**). Root filter are expressed as % of outside concentration With 60mM NaCl ap-plied varieties differed in their root xylem Na content. In IR4630 root xylem sodium content was up to 60% lower than the external Na concentration, in IKP up to 40% declining towards the end of the season and in IR31785 xylem concentrations were higher than the external ones.

The Na and K distribution within the plant at about panicle initiation stage is shown in **Fig. 4** for three varieties, grown under salinity in the field during wet seasons 1991/93/94 (WS) and hot dry seasons 1993/94/95 (HDS). Generally, Na uptake was lower and K uptake was higher in the WS than in the HDS. The highest Na and K concentrations were found in the stems. Varietal differences in cation concentration were most pronounced in the leaf blades. Na concentration increased by leaf position (descending), and K decreased. IR4630 had the lowest Na and the highest K concentrations; the reverse was true for IR31785. The strongest seasonal effect on leaf Na concentration was observed in IKP, which had low concentrations in the WS and high concentrations in the HDS. IKP also showed the most consistent cation gradient across leaf positions. The susceptible check IR31785 stood out by showing very low K concentrations in all plant tissues during both seasons.

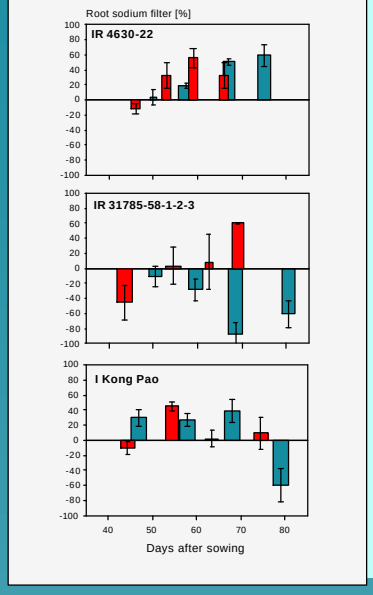
Conclusion

Varieties differ in their strategies for salinity resistance. To explain varietal differences in Na uptake and distribution, which are the result of combinations of avoidance and tolerance mechanisms, simulation models can be highly useful. We propose the following concept that combines a number of component traits for salt tolerance: Na is taken up by the roots into the xylem of the plant, driven by the combined transpiration of the existing leaf layers. Sodium uptake is regulated by a variety dependent 'root filter'. Na enters the shoot with the transpiration stream and is partly retained in the sheaths. The remaining Na enters the leaf blades as a function of the transpirational volume flow fraction of each leaf, which depends on the development stage and stomatal conductance (modulated by leaf N content and salt stress) of the individual leaf. The maximum (lethal) Na concentration in the leaves is a varietal constant.

Na seems to interact with K (Fig. 4). We assume an active uptake of K by the root, distribution in the plant via the xylem, and relocation via the phloem. K is actively mobilized from senescent leaves and fed into an incremental pool. Each plant organ has a demand function for K, modified by the amount of Na accumulated.

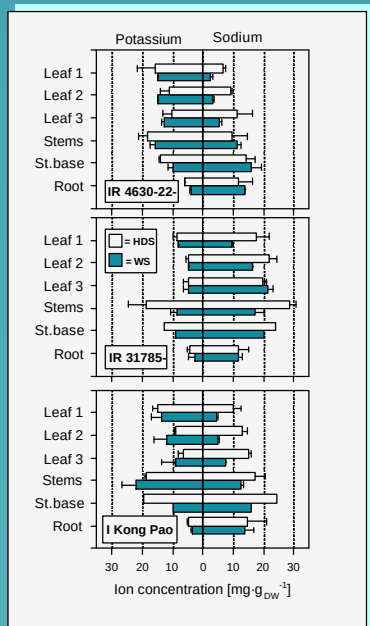
Acknowledgments

These studies were conducted in the framework of a special project on 'Rice Salt Tolerance in the Sahel' financed by GTZ (German Agency for Technical Collaboration) at WARDA's research station in St. Louis, Senegal, in collaboration with the Institute for General Botany of the University of Hamburg. We thank Dr. M.S.C. Wopereis for making Oryza_W available to us.



ig. 3 of culture solution Na concentration (Phytotron amburg, summer 1996). Data from 60mM NaCl treatment. Blue ars = high rH treatment (80%, or Sahelian wet season), red bars low rH treatment (40%, or Sahelian hot dry season) Error bars E over 4 replications.

Na uptake is regulated by genotype dependent 'root filter'



ig. 4 at panicle initiation grown in saline soil (3.5 mSc rigation water EC, field trial) during wet season 1991/93/94 (W nd hot dry season 1993/94/95 (HDS). General observations:

- **Highest Na and K concentrations in the stems (leaf sheaths**
- **Na uptake lower, K uptake higher in WS as compared to HD**
- **Na increases, K decreases with descending leaf position**
- **Strong varietal differences, strong seasonal influence**