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SUMMARY OF DOCTORAL THESIS

Name: Ould Ahmed Bouya Ahmed

Title: Sustainable drip irrigation scheduling using poor quality water under arid environment

乾燥条件下における低質水を用いた点滴灌漑の持続的用水計画

Globally, the area under irrigation is five times larger today than what it was a hundred years ago. Without irrigation, increases in agriculture to feed the world's growing population would not have been possible. In addition, as competition for fresh water increases, water of better quality would primarily be used for domestic purposes whereas, water of lower quality would be use for irrigation. Therefore, the challenge for agriculture in the future will be to maintain or even increase crop production with water of lesser quality and increase water use efficiency.

Drip irrigation system has the advantage of maintaining high water content near the plant root and thus enhancing water use efficiency. However, its performance depends on water quality as poor quality water may induce emitter clogging. Use of saline water with appropriate irrigation management techniques might help in achieving long-term sustainability in agricultural in dry areas where availability of good quality water is limited. A study on drip irrigation with low quality water for sustainable production under simulated arid environment was carried out at the Arid Land Research Center, Tottori University, and in the Tohaku National Irrigation Project area, Tottori, Japan (35°32´N and 134°13´) during 2004 and 2006. The study included the following four parts:

The first part of the study was to assess the effect of two levels of irrigation input, each at two frequencies, on sorghum (*Sorghum bicolor* (L) Moench) grain yield as impacted by available soil water after irrigation and the electrical conductivity of soil water (ECsw) in a dune sand, in a greenhouse experiment. Saline water (7.32 dS m^{-1}) at input amounts equivalent to 50% or 100% of pan evaporation was applied daily or every second day. Using the Time Domain Reflectometry technique (TDR), soil water content and ECsw were monitored simultaneously just before and 1-2 hr after irrigation. The cumulative recharge by irrigation in the top 25 cm of the profile ranged from 309 to 662 mm and it depended on irrigation input amounts, which ranged from 382 to 765 mm, and the frequency of irrigation. The potential cumulative evapotranspiration (ETc) was 578 mm. The daily recharge matched against the corresponding ETc indicated that grain yield might have been impacted by water stress in the 50% irrigation input, regardless of the frequency, but not in the 100% input treatment. The daily ECsw in the root-zone matched against the FAO threshold (13.6 dS m^{-1}) indicated the possibility of salinity stress during the late maturity stage in the 50% input treatment, regardless of the irrigation frequency, but no stress in the 100% input treatment. Though there was no water or salinity stress in the every second day irrigated 100% input treatment, the significant relative yield reduction, compared with the daily 100% input, is attributed to inherent limited available soil water capacity and rapid percolation losses between irrigations in this sand. The results indicate that daily irrigation at 100% input is the most appropriate saline water irrigation management option for this dune sand.

The second part of the study was to investigate the clogging problem induced by low quality water in Tohaku National Irrigation Project. Seven emitters of different types

were assessed for the variation in their discharge flow rate without filter during two irrigation seasons. The statistical analysis of mean discharge ratio (Dra), uniformity coefficient (Uc), and the coefficient of performance variation of emitters along a lateral line in the field (Vf) indicated that the mist spraying type emitter had the best performance for irrigation in Tohaku area, particularly when the emitter was new or only one-year old. The results suggest that the emitter line used for two irrigation season should either be replaced or washed carefully if reused for the third season.

In the third part of this study the impact of two input amounts (one half and full of open pan evaporation), two frequencies (daily and every second day), and three salinity levels of irrigation water (7.32, 9.40, and 12.50 dS m^{-1}) on the temporal dynamics of the stress indicators; water (K_w) and salinity (K_s) stress coefficients, and leaf water potential (LWP) in sorghum were investigated. The K_w for an input amount equivalent to one-half of open-pan on daily basis (EP0.50-1) ranged from 0.32 to 0.51 and K_s from 0.50 to 0.98 Kw compared with 0.51 to 0.98 for the 100% of open-pan input on daily basis (EP1.00-1) and 0.80 to 0.98 for K_s. The K_w for the 3 increasing salinity levels (S-1 to -3) ranged from 0.68 to 0.96 for S-1, 0.58 to 0.90 for S-2, and 0.43 to 0.89 for S-3, and from 0.85 to 1.00 for the control. The corresponding K_s range was 0.89 to 0.98, 0.70 to 0.96, 0.49 to 0.70, and 1.00, respectively. The LWP range for the 3 salinity levels were -1.70 to -0.70 MPa for S-1, -2.50 to -1.20 MPa for S-2, and -2.90 to -1.60 MPa for S-3 and -0.70 to -0.20 for the control. The time series statistical parameters; mean, median, CV, and the 20th percentile values (PC20), assessed to discriminate the temporal sensitivity of the stress indicator coefficients showed that CV and PC20 are equally better than median which in turn is better than mean. Sorghum grain yield depended on irrigation input amount and frequency, LWP, and the interaction involving K_W and K_S (R^2_{adj} 0.71 to 0.85). The temporal dynamics of the stress indicators (K_W, K_S and LWP) indicated that irrigation input EP1.00-1 provided the least risk with regard to water and salinity stress in relation to sorghum grain yield.

In the fourth part of the study the possibility of use of saline water for leaching salt was evaluated. In a greenhouse study, sorghum was grown on dune sand with drip irrigation using water with four different levels of salinity (5.40, 7.32, 9.40, and 12.50 dS m^{-1}) and normal water as a control in the first season. The crop was again grown in the second season but at the start of the second season the soil was leached using either 25 mm of normal water or 25 and 50 mm of saline water four times in two weeks. Using the Time Domain Reflectometry (TDR) technique, soil water electrical conductivity (ECsw) in the root zone was monitored during both the seasons. The daily ECsw, compared against the FAO threshold (13.6 dS m^{-1}), indicated the possibility that the crop would have been exposed to salinity stress under irrigation with different levels of salinity. The salinity stress was higher in the second season as compared to the first season. While the soil salinity was reduced by leaching with normal water, there was no difference ($p < 0.005$) in the salinity when two levels of saline water were used for leaching. Though there was no water stress, the significant reduction in the yield with the use of saline water for irrigation, as compared with the control, could be attributed to salt input. The results indicate that leaching with saline water just before the start of the second season could reduce the salinity of sandy soil. However, the reduction in salinity was better when leaching was done with normal water. As the amount of normal water required for leaching is rather small (less than 25 mm), this amount can easily be collected by water harvesting from rainfall in the semiarid region. With this procedure sustainability of sorghum production using saline water for irrigation in water-scarce dry area can be achieved.