

2.7 Activities of Foreign Researchers

(1) Professor Berliner, Pedro Reuven

Visiting Professor (October 2001-September 2002)

Ben Gurion University, Israel

Title: “Effect of water quality, irrigation frequency and alternating water sources on the productivity and water efficiency of halophytes”.

1. Summary of research activity for the past year.

i) Seminars presented:

- a) “Use of marginal water resources for the production of firewood and fodder in arid area”. Special lecture at the Joint Research Symposium, ALRC, Tottori University. December 6, 2001
- b) “ A simplified approach for modeling agricultural production for climate change impact assessment“ Workshop on Impacts of Climate Change on Agricultural Production in Arid Areas “, hosted by the Research Institute for Humanity and Nature, Kyoto February 10-11, 2002
- c) “Runoff Agroforestry for arid regions”. Biotron Institute, Kyushu University, 19 February 2002
- d) “Effect of inter-row polyethylene mulch on cotton production”, RIHN seminar on “soil-water-plant continuum”. Kyoto, 14 May 2002.
- e) “Validation in an arid area of an algorithm for the estimation of daily solar radiation and its use in estimating Potential Evapotranspiration in arid regions”. ALRC, 16 May 2002
- f) “Effect of polyethylene mulch on the productivity of cotton.” ALRC, 13 June 2002
- g) “Evaporative losses from micro-catchments.” ALRC, 8 July 2002
- h) “Runoff Agroforestry in the negev Desert of Israel and in the Turkana region of Kenya.” ALRC, 15 July 2002
- i) “Short rotation forestry irrigated with runoff and brackish water.” ALRC, 23 July 2002.
- j) “Estimation of incoming global radiation in arid area”. Graduate School of Bioagricultural Sciences, Nagoya University”, Nagoya, 29 July 2002

ii) Scientific meetings

- (a) Japan-China Joint Open Seminar on Combating Desertification and Development in Inland China, November 14, 2001
- (b) Open seminar “Soil-Water-Plant continuum”. Research Institute for Humanity and Nature. Kyoto, 14 May 2002

iii) Scientific visits

- (a) Kyushu University, Prof. Chikushi, Biotron Institute,

- (b) Kyushu University, Dr. Otsuki, Res. Institute Kyushu University Forests
- (c) Saga University, Prof. Cho, Department of Agricultural Engineering
- (d) Kyushu-Kyoritsu University, Prof. Kuroda and Dr. Takeuchi, Faculty of Engineering
- (e) Nagoya University, Prof. Ohta, Graduate School of Bioagricultural Sciences, Nagoya University.

2. Title of articles

- Accepted for publication
 - i. Validation in an arid area of an algorithm for the estimation of daily solar radiation. *Journal of Hydrometeorology* (American Society of Meteorology)
 - ii. The role of dew in the water and heat balance of bare loess soil in the Negev Desert: quantifying the actual dew deposition on the soil surface. *Atmospheric Research*
 - iii. Runoff Harvesting System as Part of Desertification Prevention and Sustainable Development of Desert Ecosystems. *Proceedings of the 2nd International Conference: "New Trends in Water and Environmental Engineering for Safety and Life"*, Capri, Italy, pp. 49-55.
- Submitted for publication
 - i. Water quality and irrigation frequency effects on rooting patterns of *Acacia saligna*, a leguminous shrub. Submitted to *Forest Ecology and management*.
 - ii. Turbulence in a desert plantation. Submitted to *Boundary Layer Meteorology*.
- In preparation (to be submitted within the next three months)
 - i. Evapotranspiration under advective conditions. Final draft. To be submitted to the *European Journal of Agronomy*
 - ii. The effect of inter-row polyethylene mulch on the development of cotton in an arid area. First draft. To be submitted to *Agricultural Water Management*.

3. Results

a) Validation in an arid area of an algorithm for the estimation of daily solar radiation. The Thornton-Running algorithm to estimate daily global radiation was tested at a site located in a coastal desert. A good correlation was obtained between predicted and measured values. The predictions of transmissivity for clear days were very good but a systematic underprediction was observed for the whole data set when measured global radiation exceeded 20 MJ m^{-2} . A regression analysis showed that errors in the estimated global radiation were linearly related to errors in one of the factors used in the algorithm. This factor is computed using the diurnal amplitude of air temperature and our results showed that the correlation between the measured factor and diurnal temperature amplitude was very poor. The Thornton-Running algorithm includes a correction for atmospheric water vapor content, which is usually unavailable. We

evaluated the possibility of using the saturated vapour pressure at minimum temperature in lieu of the actual measured daily average and our results indicate that this approximation works well and does not noticeably affect the estimated fluxes. A serious underestimation of daily PET was observed when the estimated values of global radiation were used in the computation instead of the measured values. An evaluation of decade values indicated that differences during the rainy period were relatively minor but a serious underestimation is evident during the dry period.

- b) The role of dew in the water and heat balance of bare loess soil in the Negev Desert: quantifying the actual dew deposition on the soil surface. During nighttime latent heat fluxes to or from the soil surface are usually very small and the absolute amounts of dew deposition accordingly very small. The detection of such small fluxes poses serious measurement difficulties. Various methods for measuring dew have been described in the literature and most of them rely on the use of artificial condensing plates with physical properties that are very different from those of soil surfaces. A system that detects the actual dew deposition *on the soil surface* under natural conditions would be advantageous and micro-lysimeters appear to be the obvious answer. The objectives of this work were to test the adequacy of micro-lysimeters to estimate condensation amounts, and to compare these amounts with those measured by a Hiltner dew balance in order to validate the long term data collected using the latter. The research was carried out at the Wadi Mashash Experimental Farm in the Northern Negev, Israel, during two measurement periods. A micro-meteorological station was installed in the field next to a modified Hiltner balance. A micro-lysimeter with an undisturbed soil sample was placed nearby. During the first period, the depth of the micro-lysimeter was 15 cm while at the second period it was 55 cm. The results show that for measuring dew, the minimum depth of a micro-lysimeter should exceed the depth at which the diurnal temperature is constant, which for a dry loess soil in the Negev Desert is 50 cm.
- c) Runoff Harvesting System as Part of Desertification Prevention and Sustainable Development of Desert Ecosystems. The lack of readily available water resources, in particular those of good quality, is the main factor in hindering the sustainable development of desert ecosystems. In arid zones runoff can be used as a supplementary source of water for agricultural purposes. In these areas runoff is frequently generated as a result of the development of a crust on the surface of the soil. The purpose of this work is to study in the field and under natural rainfall conditions soil crust generation and evaluate the effect the changes in crust permeability and roughness have on runoff production. Runoff generated on 100 m² plots was measured on six plots by a tipping bucket system. Rainfall intensity was recorded on site with a rainfall gauge (resolution 0.25 mm). On three of the six plots rainfall induced crusts had been formed during the preceding three years (CP) and on three plots the crust had been completely destroyed by cultivation with a rotary tiller (RP). Surface roughness was characterized by the surface rms height obtained from laser micro-relief measurements before and during the season. Prior to the onset of rain, the roughness for the RP plots was similar. After five rainfall events totaling 30

mm. their surface roughness had decreased significantly. Additional rainfall events did not affect the roughness of these plots. The final roughness of the RP plots was significantly different from that of the CP plots (whose roughness had not changed throughout the season). No clear correlation between roughness and runoff could be established and the latter was therefore governed by crust permeability. Runoff generated on CP and RP plots during rainfall events that occurred after 40mm of cumulative rainfall had been registered, was not significantly different. The initially cultivated plots were always rougher than the long-term crusted plots suggesting that the newly developed crusted areas in the RP plots had a lower conductivity. The results from this study indicate that roughness appears to be of limited importance in determining total runoff from micro-catchments. An additional observation is that the length of the rain-less gaps occurring during rainfall events appear to be extremely important in determining runoff efficiency.

d) Water quality and irrigation frequency effects on rooting patterns of *Acacia saligna*, a leguminous shrub. Systems based on the collection of runoff water are a viable approach for afforestation in arid and semi arid zones. Israel is characterized by winter rainfall with rare runoff pulses. The time interval between runoff events is of the order of one year with an extremely hot and dry period in between and it is therefore advantageous to store the largest volumes of water possible during a runoff event. Water will therefore percolate deep into the soil, increasing soil moisture availability allowing trees, annual crops or a combination of both to grow. Under these conditions the root distribution of trees may change throughout the dry season and the ability of the tree to adapt to a changing soil moisture environment may determine the productivity of the system. Characterizing the rooting patterns of a runoff forestry system may be instrumental in correctly interpreting above ground development of crops and shrubs and determining maximum water storage depths. A considerable amount of data is available on the above ground biomass production in forestry and combined crop-tree systems, but quantitative information concerning root development and turnover is scarce. In arid zones, aquifers with good quality water are rare, and if they exist they are used for conventional agricultural production. On the other hand brackish water aquifers are common. This source of water could be used to supplement the runoff water and thereby stabilize tree production. Wetting the soil with brackish water may alter the rooting patterns as salt stress inhibits root elongation in most plant species. In a mixed irrigated forestry system (runoff flooding of the whole plot once a year and fresh-brackish supplemental irrigation applied via drip irrigation) a rather complicated situation arises. This application scheme results in a two- dimensional heterogeneous distribution of salt concentration in the soil profile. The overall aim of this study was to monitor the spatial and temporal root distribution patterns of *Acacia saligana* trees grown in an arid zone in a simulated runoff system with supplemental irrigation. More specifically, the objectives of this investigation were: 1) to monitor the effects of brackish and fresh water on the rooting patterns of *Acacia saligna* trees in a Runoff System in an arid zone and, 2) to evaluate the effects of

irrigation frequencies (well watered, low frequency and only runoff) on the rooting patterns of *Acacia saligna* trees growing in an arid zone.

- e) Turbulence in a desert plantation The objective of this research was to study the spatial variation of the turbulent heat field as affected by a 2-D configuration of a desert, row crop. The thermodynamic effect due to the high temperature of the bare soil between the widely spaced rows, was of a particular interest. Measurements of the turbulent heat flux were taken in four points within the canopy, and analyzed using a Quadrate-Hole technique. Data conditioning procedure prior to the Q-H analysis was required due to large-scale perturbation caused by the change in wind direction in respect to the row orientation. The results of the Q-H analysis show that three of the points are characterized by the behavior usually found in homogeneous canopy under neutral conditions; most of the heat flux is transferred by, intense sweep events which occupy only few percents of the total transfer time. The fourth point, which is located at the lower part of the canopy, at the lee side of the row (a quiet zone), shows a unique pattern indicating that this point is dominated by ejection rather than sweep events. It appears that the dynamic force, induced by the shear at the top of the canopy, is dominant over the thermodynamic force as induced by the hot surface, except for the quiet zone at the lee of the plants row.
- f) Evapotranspiration under advective conditions. Arid and semi-arid regions are heterogeneous landscapes, in which irrigated fields are surrounded by arid areas. The advection of sensible heat flux from dry surfaces is a significant source of energy that may have to be taken into consideration when evaluating the evaporation from crops growing in these areas. The basic requirement of most of the common methods for estimating evapotranspiration (Bowen ratio, aerodynamic and Penman-Monteith equation) is that the horizontal fluxes of sensible and latent heat are negligible when compared to the corresponding vertical fluxes. We carried out measurements above an irrigated tomato field in a desert area. Latent and sensible heat fluxes were measured using a four-level Bowen machine with aspirated psychrometers. Our results indicate that only measurements carried out in the lowest layer are satisfactory and allow the estimation of latent heat fluxes in situations of advection.
- g) The effect of inter-row polyethylene mulch on the development of cotton in an arid area. An irrigation trial was carried out in an extremely arid zone. Three water application treatments were tested: stored water and 100 and 70% of water requirements of the cotton crop. The latter was computed multiplying the cumulative Class A Pan evaporation by a coefficient that changed throughout the season. Irrigation treatments were split according to the presence or absence of a black polyethylene cover between the rows. The six treatments were replicated four times in a fully randomized block design. Mulching increased soil temperature in the row and between them, at 5 and 15 cm depth. As a result of this difference germination percentage increased and the time to full emergence was reduced by two days. Final height was as well attained earlier by the mulched treatments. The Leaf Water Use Efficiency (computed from

single leaf measurements of transpiration and photosynthesis) was similar for all treatments throughout the season. The Canopy WUE was higher for the mulched treatment and indicated that approximately 40% of the applied water was lost by evaporation during the vegetative stage by the non-mulched treatments. Final seedcotton yield was significantly higher for the mulched treatments and the fully irrigated treatment produced the highest yield.

(2) Professor Rami Keren

Visiting Professor (October 2001-August 2002)

The Volcani Center, Israel

Title: *Soil structure and soil hydraulic properties*

My stay at the Arid Land Research Center of Tottori University has been a pleasure both professionally and socially. It was an honor to be a Visiting Professor in the ALRC and to collaborate with Prof. S. Inanaga the Director of the ALRC and with Professor T. Yamamoto, Head of the division Land Conservation. I was pleased to work closely with Professor T. Yamamoto to instruct students for their dissertations, to help undergraduate and graduate students and to conduct series of lectures on physical chemistry of soils. Thanks to Miss Kyoko Takahashi and those who have worked hard helping us to communicate and to make our stay here so enjoyable.

Summary of research

My activities in the Arid Land Research Center, Tottori University, during Oct. 16, 2001 and August 31, 2002 were as follows:

a. Symposiums and workshops

1. Key note lecture on response of saline-sodic soil to water quality: Processes and managements. Proceedings of the 40th Annual Meeting of Soil Physics Section, Japanese Society of Irrigation, Drainage and Reclamation Engineering (JSIDRE). ALR Center, Tottori University, 2001.
2. Water conservation practices assessments and wheat adaptation to semiarid regions with eroded environment. The 12 International Soil Conservation Organization Conference, Beijing, China, May 26-31, 2002
3. Effect of ESP and clay content on soil aggregate stability. The annual meetings of the Japanese Society of Irrigation, Drainage and Reclamation Engineering. Tsu - shi Mie – Ken, Japan, August 2002.

Seminars and lectures

1. Plant uptake of Boron as affected by Boron distribution between the liquid and the solid phases in soil. Kyushu University, Fukuoka, Japan. February 2002.
2. Soil properties and Combat Desertification - the agricultural approach. Arid Land Research Center, Tottori University, Tottori Japan. April, 2002.

3. The properties of clay minerals and their behavior in aqueous media. Arid Land Research Center, Tottori University, Tottori Japan. June 2002.

A Series of lectures on the topic “Soil Physical and Chemical Properties Relations”

4. Clay swelling and dispersion processes and their roles in soils hydraulic properties. Arid Land Research Center, Tottori University, Tottori Japan. June 2002.
5. Hydraulic properties of soils and their relation to water quality. Arid Land Research Center, Tottori University, Tottori Japan. June 2002.
6. Water quality assessment for irrigation in arid land regions. Arid Land Research Center, Tottori University, Tottori Japan. June 2002.
7. Kinetics of gypsum dissolution and its solubility in aqueous media. Arid Land Research Center, Tottori University, Tottori Japan. June 2002.
8. Sodic soil reclamation under semi arid and arid conditions. Arid Land Research Center, Tottori University, Tottori Japan. June 2002.

b. Research

Instructing a Ph.D. candidate on the subject: “Soil aggregate stability and hydraulic conductivity of soils with 2:1 and 1:1 clay minerals as affected by water quality”.

Titles of articles

1. Keren, R. 2001. Response of saline-sodic soil to water quality: Processes and managements. Proceedings of the 40th Annual Meeting of Soil Physics Section, Japanese Society of Irrigation, Drainage and Reclamation Engineering (JSIDRE). ALR Center, Tottori University, 2001.
2. Masae ARAI, R. Keren, T. Yamamoto and M. Inoue. 2002. Effect of Water Quality on Saturated Hydraulic Conductivity of Soils with 2:1 and 1:1 Clay Minerals. Transactions of the Japanese Society of Irrigation, Drainage and Reclamation Engineering. (Sbmitted).
3. Masae ARAI , R. Keren, T. Yamamoto and M. Inoue. 2002. Aggregate Stability Evaluation of Sodic Soils Using Water-Ethanol Mixtures
Transactions of the Japanese Society of Irrigation, Drainage and Reclamation Engineering. (Sbmitted).
4. Masae ARAI, R. Keren, T. Yamamoto and M. Inoue. 2003. Aggregate stability and hydraulic conductivity of Sodic Soils Using Water-Ethanol Mixtures. Soil Science, (In preparation).
5. Deng Xi-ping, L. Shan, S. Inanaga and R. Keren. 2002. Water Conservation Practices Assessments and Wheat Adaptation to Semiarid Regions with Eroded Environment. A review paper presented in the 12 International Soil Conservation Organization Conference, Beijing, China, May 26-31, 2002, China.
6. Communar, G., and R. Keren. Convection-dispersion transport of non-linearly adsorbed desorbed

solutes in saturated soils. *Soil sci. Soc. Am. J.* (Submitted).

Research Results

1. Response of saline-sodic soil to water quality: Processes and managements.

R. Keren

Many soils in arid to humid regions have unstable structure which makes them difficult to manage owing to their tendency to swell and disperse. Since soil permeability decreases with the square of the pore radius, a small reduction in size of the large pores due to swelling and clay movement has a large effect on soil permeability for water and gases. The favorable effect of exchangeable Ca and the deleterious effect of exchangeable Na on soil swelling and dispersion is well known. The soils responded differently to the same combination of electrolyte concentration and ESP.

The extent of swelling and dispersion of clays depends on the clay mineralogy, the composition of the adsorbed ions and the salt concentration in solution. It was concluded that the electrolyte concentration - SAR threshold values for HC and clay dispersion of arid soils are closely related. However, whether clay will leave the system or move and seal the soil depends on the extent of swelling. At any particular percentage of exchangeable Na, the influence of exchangeable Na is greater with exchangeable Mg as the complementary ion than it is with Ca.

Water infiltration is more susceptible to ESP than the HC of the soil profile for the following three reasons (1) the mechanical impact of the water drops, (2) the absence of the soil matrix which slows clay movement, and (3) concentration of electrolytes in the surface soil solution is determined solely by the composition of the applied water, because dissolution of CaCO₃ and primary minerals is too slow to affect the surface solution concentration. Thus, when water with low electrolyte concentration is applied (rain water or snow water) salt concentration in the soil surface solution remains low even for calcareous soils, and clay dispersion is possible only if the salt concentration is below the FV of the clay. Studies imply that also Mg is a deleterious ion in some circumstances. Adsorbed Mg has a specific effect on soil erosion and infiltration for montmorillonitic noncalcareous and calcareous soils and the erosion rate for Na/Mg soil is greater than the rate for Na/Ca soil. Sodic soil reclamation management was discussed.

2. Effect of Water Quality on Saturated Hydraulic Conductivity of Soils with 2:1 and 1:1 Clay Minerals.

Masae ARAI, R. Keren, T. Yamamoto and M. Inoue

The pHs of the Niigata and Tottori soil were 6.5 and 6.2, respectively, showing slight acidity; the EC were 0.23 and 0.29 dS/m, respectively. Both soils were classified as light clay according to the International Society of Soil Science. The liquid limit of the Niigata and Tottori soil was 48.3, 44.3 %; the plastic limit 29.1, 28.2 %; and the plastic index 19.2, 16.1, respectively. The liquid limit of the Niigata soil was slightly higher than that of the Tottori soil, but the difference was not significant. The X - ray diffraction patterns of the < 2 µm clay fractions revealed that smectite was the dominant clay mineral for the Niigata soil, and kaolinite and vermiculite were in Tottori soil. The final HC values when leached with the 500 me/L solution at SAR 0 and 30 were 4.99 and 2.99 mm/h for the Niigata soil, 3.63 and 7.71 mm/h for the Tottori soil, respectively. These values were taken as reference value in the calculation of the RHC. The drastic drops in the RHC of both soils occurred when the concentration of the applied solutions were

reduced to less than 10 and 5 me/L at SAR 30, respectively. The RHC of the Niigata soil and the Tottori soil dropped 69 and 71 %, respectively. The amount of the cumulative effluent volume approaching to a nearly steady RHC of the Niigata soil with 10 me/L solution at SAR 30 was about 2200 mL. Conversely, in the Tottori soil with 5 me/L solution at SAR 30, it was about 4300 mL. At SAR 0, however, the RHC of the both soils dropped drastically only when leached with DW. The amount of the cumulative effluent volume approaching to a nearly steady RHC of the Niigata soil was about 1000 and 250 mL for SAR 0 and 30 for DW. In the Tottori soil, they were about 7000 and 500 mL for SAR 0 and 30 for DW. No clay was detected in the effluent of both soils at all SAR and the all solution concentrations.

3. Aggregate Stability Evaluation of Sodic Soils Using Water-Ethanol Mixtures

Masae ARAI, R. Keren, T. Yamamoto and M. Inoue

The aggregates of most arid regions soils are not stable while testing their stability by the current wet-sieving method when using water and nearly complete aggregate breakdown occur. A modified wet sieving method that based on ethanol-distilled water mixtures was suggested for relative aggregate stability assessment for these soils. The objectives of this study were (1) to modify the wet-sieving method by using ethanol-water mixtures for assessing aggregate stability of arid region soils and (2) to evaluate aggregate size distribution resulting of initial aggregates breakdown as affected by clay content and adsorbed cation composition.

Aggregate stability was conducted for sandy clay loam and clay soils using ethanol-distilled water solution at ethanol concentration of 0, 25, 40, 50, 65, 75, 85 or 96 % (to obtain various dielectric constants in the range between 81.7 and 25.6) or by using NaCl and CaCl₂ solutions at total electrolyte concentration of 0.1 and 1 mol_c L⁻¹ at SAR appropriate to the soils' ESP. Aggregate stability decreased significantly with the decreasing of ethanol concentration in the aqueous solution. High fraction of unstable aggregates was observed after sieving in ethanol for 1 min when the wetting rate was 100 mm h⁻¹. On the contrary, 4-6 mm aggregates of both soils were stable after sieving in ethanol for 1 min, when the wetting rate was reduced to 4 mm h⁻¹. These results indicate that wetting rate is an important factor in aggregate stability determination even when the wetting liquid is ethanol. The fraction of the stable 4-6 mm aggregates decreased substantially in a relatively small ethanol concentration range, having an inflection point at a stable aggregate fraction of 50 %. The ethanol concentration in solution at the inflection point for the sandy clay loam soil was higher than that for the clay soil and increased with the ESP.

The higher aggregate stability in the presence of ethanol can be attributed to the reduction in the dielectric constant of the medium between aggregates or due to bridging of two adjacent clay particles through ethanol molecule interaction. The fact that all (most for the soil at ESP 9.3) of the 4-6 mm aggregates disintegrated at this high electrolyte concentration may indicate that the dominant mechanism involves in stabilizing the larger aggregates of the soil is the bridging of two adjacent small aggregates through a clay particle-ethanol molecule interaction.

4. Aggregate stability and hydraulic conductivity of Sodic Soils Using Water-Ethanol Mixtures

Masae ARAI , R. Keren, T. Yamamoto and M. Inoue

(In preparation))

5. Water Conservation Practices Assessments and Wheat Adaptation to Semiarid Regions with Eroded Environment

Deng Xi-ping, L. Shan, S. Inanaga and R. Keren.

About 40% of the land in the world is under arid and semiarid climatic conditions. Moreover, semiarid regions are currently under a treat of desertification due to deficiently in water for irrigation. Water is the principal constraint that limited agricultural development in these regions.

The soils in these regions are characterized by relatively high runoff / rainfall ratio and much of the rainwater evaporates through the soil surface between rainstorms. The drying process may deplete as much as 50% of the total precipitation. Therefore, soil managements to minimize both water runoff and evaporation is the primary objective to achieve in rain-fed farming under regions where rainfall is the limited factor. The following subjects were discussed: (1) Soil and water managements, increase water availability (technologies, water harvesting), water infiltration technologies, water holding capacity of soils, and minimizing water evaporation through soil surface; (2) Water use efficiency, tolerant crops to drought and cropping management; and (3) Breeding of tolerant plants for drought conditions.

6. Convection-dispersion transport of non-linearly adsorbed desorbed solutes in saturated soils.

G. Communar and R. Keren.

Analytical solutions of the classical convection-dispersion equation (CDE) have been derived for non-linear adsorption-desorption of solute in soil systems. It is assumed that water flow is steady and that the chemical equilibrium is established instantaneously. An analytical solution for a non-linear CDE was suggested by dividing an adsorption isotherm into several linear segments. The advantage of the solutions presented is that they incorporate real parameters of non-linear isotherms. The calculated data demonstrate the effects of dispersion and non-linear adsorption and desorption of a solute on the solute transport process in soil, under saturation condition.

(3) Associate Professor Guang Wen

Visiting Associate Professor (April 2002-March 2003)

University of Saskatchewan, Saskatoon, SASK. Canada

Title: Influence of application of sewage sludge, sludge and manure composts on plant Zn and Cu concentration.

Following five seminars were given:

(1). Soil Microbial Biomass and Adenosine 5'-triphosphate (ATP) as an Index of Soil Biomass Activity.

Studies of transformations of organic matter in soil require an understanding of the microbial biomass and it's activity. Over the last three decades, scientists have realized that microorganisms are central to the conversion, retention and release of nutrients and energy in soil. Therefore, any attempt to describe

these transformations in soil systems must take into account the role of the microbial biomass.

Although numerous studies have examined the abiotic parameters (temperature, water potential, oxygen, fertility, pH) which control the decomposition process, the biochemical and microbiological parameters are poorly understood. Studies of the relationships between the microbial population, microbial activity and the effects of the environment, especially during the short-term fluctuations (hours-days) due to microbial growth (decomposition) and decay, require a rapid and accurate technique for measuring the microbial biomass. In special cases, such as in oily waste treated soil, classical methods for the estimation of the soil microbial biomass, such as agar plate counts or the chloroform fumigation-incubation method, are unsatisfactory. Soil ATP measurement provides an alternative as an index of soil biomass activity.

(2). Requirement for Extracting ATP from Soil

The bioluminescence reaction of ATP with firefly luciferin luciferase was first recognized in 1947. Light emission from a firefly lantern extract could be induced by the addition of ATP and the duration of the light emission was proportional to the amount of ATP added. Soon after the principle was reported, the bioluminescence reaction became a popular sensitive technique for measuring ATP in physiological research. During the last two decades, the luciferin-luciferase system has been used increasingly for ecological and environmental studies.

Initial extractants used in soil studies were developed from methods used to measure ATP in pure cell cultures. However, when these extractants were applied to soil samples, they had severe shortcomings. The ATP concentration is very low in soils and factors such as incomplete cell lyses and extraction, adsorption by soil organic and inorganic substances, and hydrolysis of ATP during the extraction process contribute to lower the efficiency of the ATP measurement. Furthermore, it is unlikely that a single extractant would be capable of inactivating ATPase enzymes in microbial cells during extraction, and not affect the bioluminescence reaction in the assay procedure.

Methods for extracting ATP have been considerably refined in the last 10 to 20 years. The highest reported recovery efficiency of ATP from *E. coli* cells added (spiked) to soil is 99% (Webster et al. 1984). If the results from this research can be applied to most common soils generally, it would appear that a suitable extractant for soil ATP and an assay method have been found.

(3). Assessment of ionic quenching on soil ATP bioluminescence reaction.

Co-extracted ions with ATP from soils may interfere with ATP luciferin-luciferase luminescence reaction when ATP is assayed. The effects were investigated in a typical concentration range of cations and anions potentially extractable in soils. A commercial ATP assay product (Sigma Chemical Co.) was used. Significant quenching is evidenced from a concentration of 0.10 mM with Cu^{2+} and Zn^{2+} , and 1.00 mM with Ca^{2+} . The order of quenching at 1.00 mM was: $\text{Cu}^{2+} > \text{Zn}^{2+} > \text{Ca}^{2+} = \text{Na}^+ = \text{Mg}^{2+}$, while $\text{Mg}^{2+} = \text{Mn}^{2+}$, both Ca^{2+} and $\text{Na}^+ > \text{Mn}^{2+}$. The quenching was found to be much more severe with selected special heavy metal cations with quenching in the order: $\text{Ti}^{3+} > \text{Hg}^{2+} > \text{Cr}^{3+}$. Because cation quenching can be alleviated by addition of EDTA, three forms of EDTA (Mg, Na and acid EDTA) were tested for their suitability for the assay. The Mg-EDTA was found superior to the other two. Presence of PO_4^{3-} at

concentrations of 0.01 and 0.05 mM, and NO_3^- at 0.01 and 0.10 mM, significantly enhanced ATP light emission (8-13%). However, SO_4^{2-} at similar concentrations significantly decreased light emission. The quenching by CO_3^{2-} and Cl^- was only observed at high concentrations (3.20 mM and up). The order of quenching for the anions at a concentration of 6.4 mM was: $\text{PO}_4^{3-} > \text{CO}_3^{2-} > \text{SO}_4^{2-} > \text{NO}_3^- > \text{Cl}^-$. Enhanced or depressed light emission induced by ions would produce significant over or underestimation of soil ATP. While addition of Mg-EDTA may alleviate cation quenching, the interference from anions may require the ATP assay standards be prepared in a solution of similar chemical composition to that in soil ATP extracts.

(4). Attributes of compost on the physical, chemical, and biological properties of soil and the effects on plants.

The goal of this seminar is to analyze updated information to coherently discuss the various factors that necessary to be addressed for making good quality compost, and to present proper use of the product. The discussion was based on recent research and essay were collected in combination with authors' experiences with sludge and manure composting. Although considerable research utilizing other composts in similar situations is presented, the focus is on sludge and manure composts. Sewage sludge and animal manure are the major sources of organic waste produced by human society. Composting process of the waste material, some general attributes of compost, compost quality especially heavy metal contamination and compost maturity, and compost marketing, finding and developing markets were discussed.

(5). Influence of application of sewage sludges, and sludge and manure compost on plant Ca and Mg concentration and soil extractability.

Application of organic waste influences crop uptake of Ca and Mg and soil extractability, depending on the nature of the crop and the waste. Four organic wastes: (i) digested sewage sludge (DSS), (ii) irradiated sludge (DISS), (iii) composted sludge (DICSS), and (iv) composted livestock manure (CLM) were applied for two years at rates of 10, 20, 30, and 40 Mg solid $\text{ha}^{-1} \text{yr}^{-1}$. Fertilizers N and K were applied to the control treatment (CT), as well as to the waste treatments to supplement crop growth across all treatments, so that these nutrients were not treatment variables. Calcium and Mg concentrations in the tissue of lettuce, bean pods and petunias in 1990 and two cuts of lettuce in 1991, and the $\text{CH}_3\text{COONH}_4$ -extractable soil Ca and Mg were determined. Concentration of Ca and Mg in bean pods did not change to the waste application. Calcium concentration in bean pods was less than half of that in other crops. Magnesium concentration in bean pods and petunias was same, but was much lower than in lettuce. Application of DSS, in general, increased Ca concentration in the crops more than did other wastes. The extractable soil Ca was positively correlated with Ca applied with DISS ($r=0.453$, $p<0.05$). Although only a limited amount of Ca was supplied with CLM at the rate of 10 Mg solid ha^{-1} (40 kg Ca ha^{-1}), Ca concentration in petunias increased significantly, then, decreased with increased Ca application ($r=0.453$, $p<0.05$). A similar pattern with CLM was found in the extractable soil Ca. The waste application from all the sources had no influence on crop Mg concentration in 1990, possibly due to low Mg concentration in the wastes. While continuously applied DSS and DISS in 1991 linearly increased Mg concentration in both cuts of

lettuce ($r=0.867$, $p<0.01$; $r=0.670$, $p<0.01$ and $r=0.671$, $p<0.01$; $r=0.665$, $p<0.01$ for first cut and second cut of lettuce with DSS and DISS application respectively), application of CLM decreased Mg concentration in first cut lettuce. The patterns of extractable soil Mg were opposite to crop Mg concentration, as the extractable soil Mg linearly increased with CLM, and decreased with the high rate of DSS application. The ability of wastes to supply N was an important factor influencing crop N uptake (K, Ca and Mg) uptake.

I have attended 25 seminars held weekly by students to discuss recent development in crop science and plant physiology, and often gave comments, and three seminars chaired by Head of laboratory Dr. Inanaga to oversee students' research progress and to provide advice, and a conference titled "Joint Research Symposium" organized by Arid Land Research Center. I have edited a number of abstracts for students from different laboratories in the center to improve their English expression as well as to raise the academical level. It is my great pleasure to contribute to the research activities in the ALRC.

4. Refereed Journal Publications (5)

(1). Guang Wen, Jeff J. Schoenau, S. Patrick Mooleki, Shinobu Inanaga, Tahei Yamamoto, Kunio Hamamura, Mitsuhiro Inoue and Ping An (2003). Effectiveness of an elemental sulfur fertilizer in an oilseed-cereal-legume rotation on the Canadian prairies. *Journal of Plant Nutrition and Soil Science*, Germany. 166: 1-7.

Adequate sulfur (S) nutrition is critical for sustaining yields in crop rotational systems. Because of slow oxidation of elemental S (S^0), research on S^0 fertilizers has emphasized improving the short-term availability, while the long-term effects of S^0 have been overlooked. The effectiveness of a dispersible granule S^0 fertilizer (SF: Sulfer95), consisting of S^0 particles smaller than any S^0 fertilizer reported in literature ($< 44 \mu\text{m}$ in diameter), was compared to gypsum (CS: CaSO_4) and ammonium sulfate [AS: $(\text{NH}_4)_2\text{SO}_4$] in a three-year experiment (1997-1999) on a moderately S deficient Black Chernozem soil (Typic Cryoboroll in the USDA taxonomy system). The three S fertilizers were applied to canola (*Brassica rapa* L.) at 20, 40, and 80 kg S ha^{-1} , supplemented with corresponding rates of nitrogen (N) fertilizer in the first year. The control treatment (CT) received N only. Barley (*Hordeum vulgare* L.) and peas (*Pisum sativum* L.) were grown in the second and third years to test the availability of residual S. Although the yield of canola in SF fertilized treatments was only slightly higher than in CT, available S provided by SF produced a higher physiological S efficiency (PSE). Superior yields with residual SF were obtained in the second and third years by barley and peas at the rate of 80 kg S ha^{-1} applied in the first year, indicating slow oxidation of SF was beneficial to the crops subsequently grown. Over three years, the total crop S uptake was 21, 4.0 and 15% higher with SF than with CT, CS and AS, respectively.

(2). Guang Wen, T. E. Bates, R. P. Voroney, T. Yamamoto, J. Chikushi and D. Curtin (2002). A yield control approach to assess phytoavailability of Zn and Cu in irradiated, composted sewage sludges and composted manure in field experiments: I. Zinc *Plant and Soil*. 246: 231-240.

The threat of spreading diseases is a serious concern when organic wastes are applied to farmland. Irradiation and composting are effective methods to reduce pathogens. Field experiments were conducted to assess the influence of these pathogen-eliminating methods on plant availability of Zn in the

wastes. Four organic wastes: digested and dewatered (DSS), irradiated (DISS), composted (DICSS) sewage sludge and composted livestock manure (CLM) were applied during two growing seasons at 10, 20, 30, and 40 t solids ha⁻¹ year⁻¹. Available N and K in the wastes were estimated and N and K fertilizers were added to the soil to equalize available N and K supply among treatments to avoid dilution of crop Zn concentration. A control treatment (CT) received fertilizers but no waste. Lettuce, snap beans and petunias were grown in 1990, and two cuts of lettuce were harvested in 1991. The influence of waste Zn application on crop Zn concentration was studied within approximately equal crop yields. Crop Zn concentration increased in all crops treated with DSS or DISS, and often reached a maximum at the 30 t ha⁻¹ rate of application, then slightly decreased at 40 t ha⁻¹. The response of crop Zn concentration to the amount of Zn applied in the wastes was best described by quadratic equations. Waste application also significantly increased soil Zn availability index, which was a function of DTPA (diethylenetriamine pentaacetic acid)-extractable soil Zn and soil pH. The index was highly correlated with crop Zn concentration. Although Zn concentration in DICSS was similar to those in DSS and DISS, Zn applied in DICSS did not increase crop Zn concentration or soil availability index. Composting reduced the availability of Zn. The similar concentrations of Zn in DSS and DISS in both years allowed the use of a paired t test to determine the differences in crop Zn concentration caused by application of DSS and DISS. Zinc applied in DISS produced a higher Zn concentration in bean pods than Zn applied in DSS ($t > T_{0.05}$ at $P < 0.02$, $df = 15$), indicating that irradiation increased phytoavailability of Zn in the sludge. However, no similar effect was found in Zn concentrations in the two cuts of lettuce in 1991 or in soil Zn availability index.

(3). Guang Wen, T. E. Bates, S. Inanaga, R. P. Voroney, K. Hamamura and D. Curtin (2002). A yield control approach to assess phytoavailability of Zn and Cu in irradiated, composted sewage sludges and composted manure in field experiments: II. Copper. *Plant and Soil* 246: 241-248.

Organic wastes such as sewage sludges contain copper (Cu). Increased attention to environmental protection requires that wastes be treated with pathogen-eliminating procedures before application to farmland. It is not clear, however, if such procedures affect the plant availability of Cu in the wastes. This two-year field research investigated the effect of irradiation and composting on Cu availability in sludges and manure using a yield control approach. Four organic wastes [digested and dewatered (DSS), digested and irradiated (DISS), composted (DICSS) sewage sludges and composted livestock manure (CLM)] were applied at four rates (10, 20, 30 and 40 t solid ha⁻¹ year⁻¹) with supplemented N and K fertilizers. A control treatment (CT) received N and K fertilizers only. Beans, lettuce and petunias were grown in first year and lettuce were harvested twice in second year. Beans appeared to have a strong ability to absorb Cu compared with the other test crops. In general, crop Cu concentration responses to Cu applied in DSS and DISS were well described by quadratic equations. Tested by a paired t test, Cu concentration in bean pods was higher in DISS than in DSS treatment, indicating that irradiation increased phytoavailability of Cu. However, the parabolic response of crop Cu to Cu applied in DISS, suggesting that the increases were confined to the lower rates of DISS. Copper applied in DICSS did not increase

Cu concentration in any of the test crops. At a given level of applied Cu, crop Cu tended to be lower in DICSS than in DSS or DISS treatment. Sludge composting depressed phytoavailability of Cu. Copper concentration in CLM was much lower than in sludges and sludge composts, but application of CLM increased Cu concentration in bean pods. The patterns of Cu concentration in the two cuts of lettuce in 1991 to Cu applied in CLM were similar, where low rates of CLM application slightly reduced Cu concentration, then the Cu concentration increased with increased rates. The dynamics of available Cu supply were different in the sludge composts and manure composts.

(4). T. Yamamoto, M. Yamada, Guang Wen and A. Yuya (2002) Application of recycling materials for improving soil quality in arid lands. *Journal of the Japanese Society of Irrigation, Drainage and Reclamation Engineering*. 70: 797-600 (in Japanese)

(5). S.P. Mooleki, J.J. Schoenau, G. Hultgreen, G. Wen and J.L. Charles (2002). Effect of rate, frequency and method of liquid swine manure application on soil nitrogen availability, crop performance and N use efficiency in east central Saskatchewan. *Canadian Journal of Soil Science*, 82: 457-467

5. Significance of Research Results

The publication and acceptance for publication by the prestigious journals mentioned above indicated the significance of the research results. Studying across a wide range of necessary elements in plant nutrition will benefit dryland crop production and quality improvement. While I am satisfied with my research and achievements in the year 2002 term, I anticipate more research results will be produced and published in the near future.

(4) Associate Professor Mehmet Aydin

Visiting Associate Professor (September 2002-August 2003)

Mustafa Kemal University, Faculty of Agriculture, 31040, Antakya, Turkey.

Title: *Modelling impact of climate change on agricultural production*

My activities have been performed mainly in the Subdivision of Water Resources, headed by Prof. T. Yano.

Summary of research activities for 6 months

My research activities have been focused on two major topics: 1) Modelling impact of climate change on agricultural production in arid areas, 2) Effects of saline irrigation on root water uptake. These topics are related to the ongoing research program at the Arid Land Research Center (ALRC).

Seminars

1. Quantitative description of root-water uptake under field conditions. Department of Agricultural and Environmental Biology, Graduate School of Agricultural and Life Sciences, the University of Tokyo. February 13, 2003.
2. Estimation of actual evaporation from bare field soil. Arid Land Research Center, Tottori University. February 26, 2003.

3. Quantification of water uptake by roots from individual soil layers. Arid Land Research Center, Tottori University. March 19, 2003.

Lectures

A series of informal lectures were given to graduate students of the Water Resources Subdivision:

1. Soil-water content/potential
2. Saturated and unsaturated hydraulic conductivity
3. Quantification of soil-water flux in plant rooting zone
 - a) Water flux through the soil matrix (upward flux, downward flux)
 - b) Water flux through the plant roots

Assistance to students, and editorial activities

1. Advising the M. Sc. thesis research work of one student (Mr. Yoshihiro Egami).
2. Editing the Ph. D. thesis (in English) of Mr. S. L. Yang.

Participation in national and international meetings

1. Annual Joint Research Symposium of the Arid Land Research Center, Tottori University. ALRC, Tottori-shi, December 3, 2002.
2. International Workshop: Impacts of Climate Changes on Agricultural Production in Arid Areas. Research Institute for Humanity and Nature (RIHN), Kyoto. January 22-23, 2003.

Professional meeting

Round-table discussions: Impact of climate change on agricultural production in arid areas. RIHN, Kyoto. September 26-27, 2002.

Participation in preparation of proposals for an international project

The following project proposals were prepared in close collaboration with Turkish colleagues and Prof. T. Yano for submitting to the Scientific and Technical Research Council of Turkey (TUBITAK): Impact of Climate Change on Agricultural Production in Arid Areas (Joint Research Project of RIHN-Japan and TUBITAK-Turkey): (1) Simulation of soil-water-climate and plant relationships in Seyhan Plain under changing global climate, (2) Quantification of C and N dynamics in croplands of Seyhan watershed in changing global climate and land uses.

Publications

1. Aydin, M., 2003. Modelling impact of climate change on agricultural production. Proceedings for the ICCAP Workshop. Research Institute for Humanity and Nature, Kyoto. January 22-23, 2003.
2. Aydin, M., Yano, T., Kilic, S., 2003. Dependence of zeta potential and soil hydraulic conductivity on adsorbed cation and aqueous phase properties. *Soil Sci. Soc. Amer. J.* (In review).

3. Evrendilek, F., Kilic, S., Aydin, M., 2003. Quantifying ecosystem productivity of Seyhan watershed under human disturbances. Proceedings for the ICCAP Workshop. Research Institute for Humanity and Nature, Kyoto. January 22-23, 2003.
4. Yang, S. L., Yano, T., Aydin, M., Kitamura, Y., Takeuchi, S., 2002. Short term effects of saline irrigation on evapotranspiration from lysimeter-grown citrus trees. *Agric. Water Manage.* 56(2): 131-141.
5. Yang, S. L., Aydin, M., Yano, T., Li, X., 2003. Evapotranspiration of orange trees in greenhouse lysimeters. *Irrig. Sci.* 21: 145-149.

Articles under preparation

6. Aydin, M., Yano, T., Yang, S. L. Test of a simple model for estimating actual evaporation from bare field soils.
7. Egami, Y., Yano, T., Aydin, M., Effects of saline irrigation on water uptake by maize root.

Research results

1. Modelling impact of climate change on agricultural production

This study deals with the interrelationships among regional climate change, basin hydrology, crop production, irrigation system, and agricultural economics. A flow chart (framework) was built to develop a simulation model for quantitative analyses of relationships among climate change prediction, regional hydrological regime, micrometeorology, soil salinity, crop response (water consumption and growth), irrigation water demand and farming system. Within this framework, conceptual models of all topics were designed to get necessary feedback from others. (The outcomes of the study were presented at International Workshop: Impacts of Climate Changes on Agricultural Production in Arid Areas. Research Institute for Humanity and Nature (RIHN), Kyoto. January 22-23, 2003).

2. Effects of saline irrigation on water uptake by maize roots

A lysimeter experiment was designed in order to investigate root water extraction under saline conditions. This research is currently performed with Professor Yano and the master student, Mr. Egami. Three weighing lysimeters installed in a greenhouse were filled with sandy soil. The soil is an Arenosol (silicious sand, Typic Udipsamment). Average dry bulk density of the sand in lysimeters is 1.50 g/cm³. The Maize will be planted in the lysimeters and surrounding area in spring. Three treatment regimes (two salinity levels of irrigation water, and control) will be applied to three respective lysimeters equipped with TDR sensors and soil moisture probes. The results will be reported in a M. Sc. thesis (Mr. Yoshihiro Egami).

(5) Associate Professor Kamal El-Siddig

Visiting Associate Professor (October 2002-September 2003)

Agricultural Research Corporation (ARC), Sudan

Title: *Biochemical responses to salt and water stress in seedlings of Psidium guajava, Grewia tenax and Tamarindus indica.*

Broadly, I am interested in physiological and biochemical characteristics of woody plants that confer salinity and/or drought tolerance. I work from the whole plant level down to the molecular level in order to identify physiological and biochemical variations in response to abiotic stresses. The results of this work are multifaceted: 1) to learn how physiological and biochemical processes are integrated into growth responses under stressful conditions, 2) to elucidate the role of organic and inorganic solutes in mediating osmotic adjustment during the stress, and 3) to integrate this information into a predictive model which will help identify rapid methods of clonal selection of tolerant genotypes under stress conditions.

On-going Experiments

Experiments are being conducted to determine the sensitivity of germination and early seedling growth of *Grewia tenax* and *Tamarindus indica* to salt and water stress using seed sources representing different provenances in the Sudan. Germinating seeds are exposed to progressively higher concentrations (0.0, -0.2, -0.4, -0.6 and -0.8 MPa) of NaCl and PEG. Objective is to investigate the extent of osmotic and specific ion effects on germination and early seedling growth during exposure to NaCl-induced salt stress and PEG-induced water stress. In this experiment, details of germination characteristics and the status of soluble carbohydrates in embryonic axis and cotyledons during the first phase of germination and plant development will be investigated.

Student Assistance

A good portion of my time is devoted to student guidance at the post-graduate level. Currently, I am supervising one Ph.D. student working on "Growth, physiology and diversity of *Grewia tenax* from geographically diverse populations in the Sudan and one M.Sc. student working on salinity tolerance of *Phaseolus vulgaris*.

I am also helping the staff and students in editing English manuscripts for journal as well as conference presentations.

Professional Contacts

1. University of Kobe, Faculty of Agriculture, Department of Agricultural and environmental engineering, Water Environment Laboratory, Professor Takeshi HATA & Dr. Abdelhadi A.W.,
2. University of Kyoto, Faculty of Agriculture, Participation in the Third World Water Forum, Theme (1-10), Agriculture, Food & Water March 20, 2003

Manuscripts Submissions/ Preparations

El-Siddig, K., G. Ebert, A. M. Ali and S. Inanaga. Salt Effects on Emergence and Early Seedling Growth of *Tamarindus indica* L. (*Seed Science and Technology*).

El-Siddig, K., B. A. El Tahir, P. Amin, J. Gebauer, G. Ebert and S. Inanaga. *Grewia tenax*: A potential New Small Fruit for the Sudan (*Angewandte Botanik*).

El-Siddig, K., G. Ebert, A. M. Ali, and S. Inanaga Growth and Photosynthesis of *Tamarindus indica* L. Seedlings under Salt and Water Stress (in preparation)

El-Siddig, K., G. Ebert, A. M. Ali and S. Inanaga. Biomass Production and Mineral content of *Tamarindus indica* L Seedlings under Water and Salt Stress (in preparation)

Paper Presentations

1. El-Siddig, K. (2002). Salinity Problems in the Sudan. A paper presented at the National Joint Research Meeting held at the ALRC, Tottori on December 3th, 2002.

Summery

Total area of salt-affected soils in the Sudan is 4.8 million ha, of which 2.1 million ha is saline and 2.7 million ha is sodic soils. The majority of salt-affected areas in the Sudan are located in the low rainfall regions in Northern Sudan in the higher terraces along the Nile River, South Khartoum, North Gezira and the White Nile Scheme due to climate conditions (desert, semi-desert and semi-arid), natural causes of weathering of salt bearing rocks, and poor soil and water management in irrigated areas including insufficient drainage system. Production potential of these soils has deteriorated with serious effects on crop yields. Technologies and resources available to farmers are very limited, consequently resulting in total abandonment of their lands. Due to the severity of the problem developed in some areas, the average yield per unit land is extremely low, about 40 percent of normal soils. Hence, the economic condition of the larger mass of the population in these areas has been gradually affected, leading to poverty and consequent migration of high numbers of people from rural areas to urban centers seeking employment or supplementing their incomes. Although salinity problems have long been identified in the Sudan, research in this field was neglected and sporadic. As a consequence, many practical problems still remain unsolved. This was attributed to the abundance of good arable land and the lack of severe salt problems in irrigated schemes. However, since the trend is towards intensively irrigated agriculture and utilization of marginal lands, which are often salt-affected, there is a pressing need for more efforts been taken to establish guidelines for utilization of these lands. In order to maintain successful agriculture in the present irrigation schemes such as the Gezira, which contain some salts though not enough to take them out of production, and in order to avoid failure in the development of newly established projects, more exact and detailed information is required on the physical and chemical properties of the soils, the effect of salts on plant growth, and on the quality of irrigation water, particularly if underground water is to be used. In this respect the newly re-emerging Soba Salinity Research Station of the Agricultural Research Corporation can play a leading role through co-operation with existing national institutes such as the National Council for Research and the Institute of Environmental Studies of the University of Khartoum which are also engaged in soil pollution studies. The program of work at this station covers a wide range of research pertaining to the field of saline and sodic soils reclamation, such as the assessment of leaching and drainage requirements, water needs of crops, use of organic and chemical ameliorants, establishment of a salt-tolerance index, economics of reclamation and management, etc.

2. El-Siddig, K. (2003). An overview of scientific cooperation between the Arid Land Research Center and the Agricultural Research Corporation (ARC), Presented on the occasion of the visit by H.E. Prof. Dr. El Zubair B. Taha, Minister for Science and Technology, Republic of the Sudan, Tottori, December 15, 2002

Summary

The scientific cooperation between Tottori University, Japan and the Agricultural Research Corporation (ARC), Sudan dates back to November 1st, 1998, when the President, Tottori University and the Director General, ARC signed an agreement for promotion of scientific cooperation in joint research, scholarly exchange, student exchange and information exchange.

Specific facts and figures are tangible proof of the productive cooperation between the two institutions across the above-mentioned dimensions. About 11 ARC Scientists out of 38 worldwide have participated in the Visiting Foreign Research Fellowship Program, since it began in 1990. High-level visits have been exchanged between the two institutions. Prof. S. Inanaga, Director, ALRC visited the Sudan in September 1997 to explore the potential of academic and research collaboration with ARC. Prof. S. H. Salih, Director General, ARC visited Japan in October 1999 to participate in the 50th anniversary celebrations of Tottori University and to probe means to further scientific cooperation. Prof. A. A. Gunief, former Minister for Agriculture and Natural Resources, visited Japan in December 2000 and he was a guest speaker at the International Symposium of the ALRC.

As an effort to expanding closer relationships with ARC, Prof. Inanaga, Director of the ALRC, will visit the Sudan during December 2002. In this visit, he will discuss the possibility of selecting the ARC as a partner in a collaborative research project aimed at combating

desertification in drylands of world. It is anticipated that this project will develop improved solutions, through a multidisciplinary research, to one of the most important environmental problems of the arid and semi-arid tropics, namely desertification and land degradation with its consequent loss of biodiversity, genetic resources and carbon stocks.