1. Research Activities (Apr. 2008-Mar. 2009)

1.1 Outline of Research Activities

(1) Center

Arid Land Research Center (ALRC) is an independent department of Tottori University and at the same time is a National Joint-use Research Facility. The mission of the ALRC is to conduct research on desertification and to develop sustainable agricultural practices in arid and semi-arid areas. The door is open to all teachers of universities who are engaged in this field of study.

Tottori University had undertaken the 21st COE Program "Program for Arid Land Science" for five years, terminated in March 2007. The 21st COE Program had contributed to promoting arid land science, development of human resources that made young scientists more creative and lead their scientific field, and establishing international networks of arid land science and education. For further development of the achievements of the last 21st COE Program, Tottori University applied the Global COE Program "Global Center of Excellence for Dryland Science" to the Ministry of Education, Culture, Sports, Science and Technology in 2007, and it was adopted.

The aim of this program is to construct the new arid land science that is unparalleled worldwide. The ALRC etc. (including the predecessor), have accumulated knowledge and technology of plant production and vegetation recovery in sands over the past 80 years. We are advancing this knowledge and technology to those that are used easily for the arid lands on the world. To achieve our goal, we fuse knowledge and technology of public health. The mission of this program is to contribute towards environmental sustainability through development of technical package that will be easily adopted by arid land inhabitants. Achievement of this objective forms the foundation of designing our national arid land science as a worldwide top-level program in this field. Consequently this will contribute to increasingly technological support of Japan as a UNCCD ratification country.

In 2001, we started for the Core University Program (by JSPS) focusing on combating desertification and developmental utilization in inner area of China between Arid Land Research Center, Tottori University and Water and Soil Conservation Research Institute, CAS in China.

Organization, Management, and Funding Subsidies

ALRC is managed by the Director, a Conference composed of professors and associate professors, a Board of Management composed of members from outside as well as professors of ALRC, the five research divisions, the office section and the technical section. In practice the Conference and the Board of Management operate our Center.

The five divisions are:

1) Climatology and Water Resources
2) Biological Production
3) Afforestation and Land Conservation
4) Socioeconomics
5) Health and Medicine

The full-time divisions from 1) to 4) have five professors, six associate professors and three assistant professors. The other division has one associate professor. The all division has two visiting professors and one associate professor from Japan and three visiting professors from abroad. In addition, 12 project

researchers are stationed at ALRC. Eleven office staff (six clerks and five associate clerks), four technical officers and a research support technician support the research and education.

Joint-Use Research, Education, Publication

During the fiscal year of 2008, 59 Joint-Use Researchers (Teachers from national and private universities) were attached to the Center. The number of students as of October 2008 is 40 (20 Ph.D. Students, 14 Master Students, 3 Undergraduate Students, 3 Research Students).

Seminars were often held by a large number of internal and external experts. The foreign visiting professors periodically give seminars.

Annual report has been published since the establishment of ALRC, which provides a brief overview of the activities in its various divisions and also summarizes our research and education.

The seminar of Joint Research was held on December 2, 2008 at Arid Land Research Center, Tottori University.

On September 8-9, 2008, Core University Program 'CAS-JSPS Core University Program Japan-China joint open seminar on combating desertification and development in inland China of year 2008' was held in Tottori, Japan.

(2) Divisions

1) Division of Climatology and Water Resources

Prof. Masato SHINODA (Climatology)

The climatological subdivision conducts research on eco-climate system dynamics in arid region; interaction between the large-scale climate and terrestrial ecosystems (including agricultural ecosystems) through water, energy, and carbon circulation. Focus is placed on climate change analysis in arid region, drought sciences, and early warning system of meteorological disasters. We also promote research on dust emission processes in Mongolia that are linked to the arrival of aeolian dust to Japan. Major study topics are as follows:

(1) Drought experiment in a Mongolian grassland (Grants-in-Aid for Scientific Research from the Japanese Ministry of Education, Science, Sports, and Culture)
(2) Climate memory dynamics of terrestrial ecosystems over the Asian-African arid region
(3) Developing an early warning system of drought and dzud in Mongolia (JICA project)
(4) Developing a biogeophysical model simulating the dust emission processes (the global center of excellence program for dryland science of Tottori University)

Prof. Hisao ANYOJI (Irrigation Engineering)

The irrigation engineering subdivision is carried out research on efficient use of water in irrigation, accurate estimation of plant transpiration and soil evaporation and reduction of soil evaporation in irrigation in order to prevent the desertification and to develop the sustainable agriculture in arid and semiarid regions.

In 2008, our efforts in Japan have been made to carry out research on hydraulic design of irrigation systems and reducing of soil evaporation by sand mulch. We collected data on irrigation at the national water research center in Egypt. Also, we exchanged information of irrigation efficiency in Egypt with researchers in the national water research center. We carried out the field survey on irrigation and drainage

at Dakhla Oasis in the Egyptian West Desert.

Cooperative researches had been conducted with the following researchers: Professor Watanabe Tsugihiro (Research Institute for Humanity and Nature), Associate professor Noborio Kosuke. (Faculty of Agriculture, Meiji University) and Assistant professor Aoda Tadao. (Faculty of Agriculture, Niigata University). The titles for these research projects are listed in the joint research section of this Annual Report.

Assoc. Prof. Reiji KIMURA (Meteorology)

The Meteorology Subdivision conducts research as follows:

(1) Quantitative analysis of heat fluxes in arid land.

(2) Monitoring and modeling of surface moisture by combining the meteorological and remote sensing data.

(3) To make clear the physical mechanism for preventing the dust outbreak by vegetation in northeast Asia.

Research grants in the fiscal year include:

- Research on the land surface processes in the dust source regions – With the purpose of reflecting to the policy for controlling the dust emission

  Japan Society of the Promotion of Science Grants-in-Aid for Scientific Research (B), 2008-2011 (Project Leader: R. Kimura)

- Dynamics of drought memories

  Japan Society of the Promotion of Science Grants-in-Aid for Scientific Research (A), 2008-2012 (Project Leader: M. Shinoda)

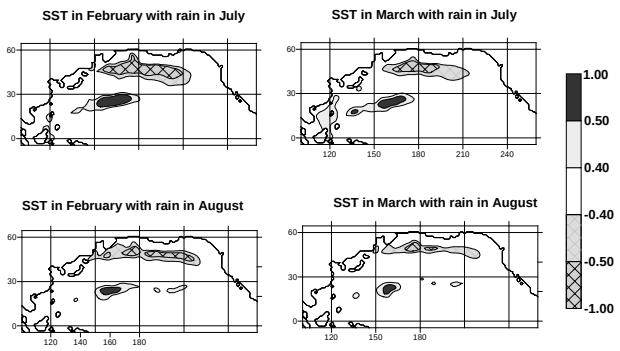
- Research on the efficient water use in Nile river basin

  Japan Society of the Promotion of Science Grants-in-Aid for Scientific Research (B), 2007-2009 (Project Leader: K. Hattori)

Overseas research activities during the fiscal year include visits to (1) Shenmu district of China to observe the heat and water balances in Liudaogou basin, (2) Bayan Unjuul of Mongolia monitoring the dust emission, (3) Lanzhou of China to determine the observation place for dust emission with staff of CAREERI (Cold and Arid Regions Environmental and Engineering Research Institute), and (4) Rashda Village of Dakhla oasis of Egypt to do the interdisciplinary study on the system of irrigation and drainage with social economics researchers.

Assoc. Prof. Hiroshi YASUDA (Hydrology)

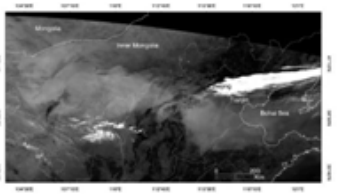
The division of Hydrology is studying water budget, environmental monitoring and modeling on water in arid land. Especially the division is focusing on fluctuation of precipitation time series, groundwater recharge mechanism, and transport in unsaturated soil in arid land. This fiscal year tackling to analysis of precipitation time series was emphasized as shown in published papers.



2) Division of Biological Production

Prof. Atsushi TSUNEKAWA (Conservation Informatics)

The Conservation Informatics Subdivision conducts research on the monitoring and modeling of the plant production and ecosystem change in the dry lands. Particular efforts are being made to clarify the interaction between the atmosphere and the land surface (vegetation and soil) through water and dust, and to develop methodologies for evaluating the sustainability of ecosystems and local communities in dry lands. The research of the subdivision is driven by combining the use of information technologies such as numerical modeling, remote sensing and geographic information systems (GIS); field observations; and experiments using Center's facilities. The main research topics in the fiscal year were as follows:



Asian aeolian dust observed by MODIS on 28 April 2005

- Monitoring the habitat environment of Mongolian gazelles in the steppe
- Research on the photosynthesis and water use efficiency of *Jatropha curcas*

Research grants in the fiscal year include:

Evaluation of effects of habitat fragmentation by man-made structures on endangered Ungulates in Mongolian grasslands

Japan Society of the Promotion of Science Grants-in-Aid for Scientific Research (A), 2006-2009 (Project Leader: A. Tsunekawa)

Overseas research activities during the fiscal year include visits to the Institute of Soil and Water Conservation (ISWC) of the Chinese Academy of Science (CAS) in the Central China to work out a master plan for developing a community-based participatory system for combating desertification in Inland China and deploying environmental education in the decertified area. The Arid Land Research Center co-sponsored the Ninth International Conference on Dryland Development held at Alexandria, Egypt on November 7 to 10, 2008. I made oral presentation at the plenary session of the Conference under the title of "New challenges of science and technology in dryland development - bridging dryland science and on-the-ground practice".

Assoc. Prof. Ping AN (Plant Ecophysiology)

Physiological responses of plants to salt and drought stresses

Assoc. Prof. Mitsuru TSUBO (Plant Production Science)

Research activities of the Plant Production Science Subsection are carried out in a wide range of fields such as crop ecophysiology, micrometeorology, ecoclimatology and agrometeorology. A research technique employed in the subdivision is simulation modelling, and also field work and indoor experiment are conducted to built and test plant growth and production models. The current research topics are:

- Plant canopy structure and radiation balance under stressed conditions of water
- Water movement in soil-plant atmosphere continuum under dry conditions
- Plant response to drought
- Model development of plant growth under drought
- Risk assessment of plant production under drought
- Framework of a drought early warning system.

The major research activities during the fiscal year were summarized as follows:

- Quantifying vegetation in Mongolian steppes
- Modelling plant production in the Loess Plateau, China

Assist. Prof. Wataru TSUJI (Crop Ecophysiology)

The Crop Eco-physiology Subdivision conducts research on the elucidation of eco-physiological characteristics of crops, and development of appropriate cultivation technology in arid land. Particular efforts are being made to clarify the mechanisms of drought and salt resistance in several crops, and to develop new crop cultivation technology to achieve higher yield under drought stress condition. The research of the subdivision is driven by combining the basic research in Japan using the Center's facilities and applied research at real drylands in abroad. In the fiscal year, I continued the experiments in ICRISAT (International Crops Research Institute for the Semi-Arid Tropics).

The main research topics in the fiscal year were as follows:

- Demonstration of cultivation technology by "defoliation" to increase grain yield and to enhance water use efficiency under drought stress condition.
- Inspection of "seed-hardening" technology to enhance germination and initial growth under drought stress condition.
- Analysis of responses to nutrient and water in the soil in *Jatropha curcas* L., biodiesel plant.

Research grants in the fiscal year included:

- Development of theoretical model and its demonstration for cultivation technology by defoliation to improve water use efficiency in dryland agriculture.

  Japan Society of the Promotion of Science, Grant-in-Aid for Young Scientists (B), 2007-2009 (Project Leader: W. Tsuji)
- Analysis of mechanisms of salt tolerance in buckwheat.

  Japan Society of the Promotion of Science, Grant-in-Aid for Scientific Research (C), 2007-2009 (Project Leader: A. Matsuura)

Overseas research activities during the fiscal year included visits to ICRISAT for investigation and experiments, and to Alexandria for participation of 9th International Conference on Development of Drylands, Sustainable Development in Drylands -Meeting the Challenge of Global Climate Change-.

Assist. Prof. Takehiko ITO (Animal Ecology)

The Animal Ecology Subdivision conducts research on the ecology of wild animals and conservation of ecosystem and biodiversity in drylands. Main targets are ecological and conservational study on wild large herbivores, such as Asiatic wild ass and Mongolian gazelle, inhabiting Mongolia. We use satellite tracking to describe their long distance movements, and combine the use of remote sensing, geographic information systems (GIS), and field observations to analyze factors of their habitat selection and movement, and influences of climate fluctuation and artificial constructions on them.

Wild Bactrian camels in Great Gobi A Strictly Protected Area, Mongolia

In the fiscal year, we surveyed vegetations in the habitat of wild ungulates tracked by satellite in Mongolia. We are collecting their location data through the internet, and analyzing their movements. We started a new research project on plant-animal interaction, mainly seed dispersal by large endangered mammals including the wild camel and Gobi bear, in Great Gobi A Strictly

Protected Area in Mongolia.

Research grants in the fiscal year include:

Evaluation of effects of habitat fragmentation by man-made structures on endangered ungulates in Mongolian grasslands

Japan Society of the Promotion of Science Grants-in-Aid for Scientific Research (A), 2006-2009 (Project Leader: A. Tsunekawa)

Overseas research activities during the fiscal year include field researches in Mongolia, and attending international conference in China, India, and Egypt.

Assist. Prof. Tomoe INOUE (Crop Physiology)

Research has been conducted to identify the morph-physiological parameters that is available for selection criteria on breeding for drought tolerance in wheat, and to improve supplemental irrigation for further effective use of scarce water in the arid land. In the fiscal 2008, in collaboration with scientists at the International Center for Agricultural Research in the dry areas (ICARDA, Syria), I studied on the contribution of pre- and post-anthesis assimilates to grain yield of synthetic hexaploid wheat derivatives, durum wheat and spring bread wheat genotypes differing in drought tolerance under rainfed and supplemental irrigation conditions.

Also joint research on the mechanisms of water and nutrient flow from host plants to *Striga hermonthica* which is the noxious root parasitic weed and one of the serious constrains on crop production in the arid land was conducted with scientists at the Sudan University of Science and Technology. In this cropping season, our research was focused on the stomatal response of Striga and its host sorghum under different soil water regimes.

Overseas activities during the fiscal 2008 include visit to ICARDA to conduct joint research on drought tolerance in wheat under the Global COE Program. And I visited the Sudan University of Science and Technology by the Asia Africa Science Platform Program to conduct the research on *Striga*.

3) Division of Afforestation and Land Conservation

Prof. Norikazu YAMANAKA (Revegetation Science)

The Revegetation science subdivision conducts research on the revegetation in arid areas based on plant ecology. Main research topics of revegetation science subdivision are as follows.

- Studies on the maintenance mechanisms of plant community in arid areas.
- Studies on the ecosystem restoration in arid areas.
- Studies on the drought and salt tolerance of trees and improvement of stress tolerance.
- Studies on the vegetation dynamics in coastal sand dunes

Root investigation in a *Tamarix* forest of Inner Mongolia, China

As the overseas activities of the fiscal year, the research on ecosystem restoration was carried out in the Loess Plateau of China in May, October 2008 and February 2009. In June 2008, the research on root system of *Tamarix* forest was carried out at salt accumulated areas of Inner Mongolia, China.

In Japan, study on the spatial distribution and seasonal change of nitrogen was carried out in the Tottori

coastal sand dunes. Experiments on the salt tolerance of *Tamarix* species, the effects of salt stress to the growth and ectomycorrhizal symbiosis of pine and the osmotic adjustment mechanisms of trees were conducted using facilities of the Center.

Prof. Mitsuhiro INOUE (Soil and Water Management)

Our central challenges are research on the reduction of soil degradation (soil erosion and salt accumulation), and on developing optimal soil and water management for sustainable agriculture in arid region. Particular efforts are being made to develop a proper technology for the land conservation to prevent soil degradation. I made an oral presentation on the accuracy of dielectric moisture probes under saline condition in The 2nd International Salinity Forum at Adelaide (Australia) in April, 2008, and published the result in the Journal of Soil Use and Management. I belong to agricultural production group in the Global Center of Excellence (GCOE) program, and have clarified interrelation of irrigation frequency and manuring in affecting growth and water use efficiency of wheat under arid condition, and published the result in the Journal of Food, Agriculture and Environment. We obtained the outside funds of the Grant-in-Aid for Scientific Research (Saline Water Irrigation Management for Sustainable Agriculture in Arid Region), the Next-generation Industrial Development Project of Local Resources (Research Development on Water-saving Vegetable Cultivation using Recycled Products) and some others. My group has two doctoral students (international), and seven master's students under my direct supervisor, sixteen joint researchers, three postdoctoral researchers and a visiting professor. Three master's students (Ryosuke MAKINO, Hirokazu SAKAI, and Shinichi KUBOTA) participated in the International Training Program supported by JSPS and studied for ten months doing experiment in Tunisia, Syria and China, respectively. Overseas research activities during the fiscal year included visits to Australia (April), China (Aug/Sep 2008, Feb/Mar 2009), Mauritania and Qatar (Nov.), Egypt (Nov.), and Tunisia and Syria (Dec., Jan.). Main research topics during the fiscal year were (1) Effect of saline water on measurement of soil water content using dielectric moisture sensor, (2) Effect of soil amendments or mulching materials on crop production under saline water irrigation, (3) Water-saving vegetable cultivation using sub-surface drip irrigation, (4) Reduction of salt accumulation or wind erosion using recycled materials, (5) Soil physical properties of arid regions.

4) Division of Socioeconomics

Assoc. Prof. Takayuki ANDO (Socioeconomics)

The Socioeconomic Subdivision aims to establish environmentally and socially sound technologies for cultivation and utilization of biofuel feedstock which would contribute to local people and their societies in developing countries as a part of investigation and application of biological resources in dry land. A study on *Jatropha curcas* L. was commenced as a biofuel feedstock because this plant has drought-resistant properties and it will be well adapted to the harsh environment of desert margins so it can be used to help to alleviate rural poverties and to improve their livelihood.

Test farm in Tanzania

The main activities in fiscal 2008 were:

(1) Formulation of a project proposal of *Jatropha* and establishment of three experimental farms in the

United Republic of Tanzania in semi-arid zone in Africa.

(2) Conclusion of the Agreement of Academic Exchange and Cooperation between Tottori University and the National Institute of Forestry, Agricultural and Animal Research (INIFAP) of the United Mexican States, where is located at the north end of the center of origin of *Jatropha curcas*.

Three experimental farms, a total of about 40 hectares, were established in Kilimanjaro Region, Morogoro Region and Pwani Region in collaboration with Sekisui Chemical Co., Ltd. and the test cultivation of *Jatropha curcas* was started.

An outline of the collaboration work was presented in the Ninth International Conference on Dryland Development in November, 2008 in Alexandria, Egypt.

5) Division of Health and Medicine

Visiting Assoc. Prof. Shinji OTANI (Health and Medicine)

The Health and Medicine Division conducts research on specific diseases in arid and semiarid areas and health disorder caused by Asian dust. The occurrence of Asian dust events is a frequent problem, with associated health issues throughout Northeast Asia. We research comprehensive measures against Asian dust in collaboration with other groups.

The main research topics in the fiscal year were as follows:

- Evaluation of Asian dust events on the daily symptoms of healthy subjects in Japan
- Health survey of nomads in Mongolia

(3) Foreign Researchers

Dr. Ahmed ElTayeb OSMAN (Range and Pasture Management)

June 2007 – May 2008

Arabian Peninsula Regional Program,

International Center for Agricultural Research in the Dry Areas, Dubai, UAE

Title: Water use efficiency of forage grasses from arid environments with particular emphasis to root development, soil moisture depletion and carbohydrate reserves

Research

Experiment 1

Water use efficiency of forage grasses from arid environments with particular emphasis on root development, soil moisture depletion and carbohydrate reserves.

Abstract

Indigenous perennial grasses are widely distributed in the United Arab Emirates and other countries of

the Arabian Peninsula (AP). Their survival under limited rainfall and heavy utilization in open grazing lands, suggests a potential role as forage and for rehabilitation of degraded rangelands. Forage production, water use efficiency, root development and carbohydrate reserves were investigated for three grasses of the Arabian Peninsula and one exotic species. The grasses were: Buffel grass (*Cenchrus ciliaris* L.); dakhna (*Coelachyrum piercei* Benth.) Bor. and da'ay (*Lasiurus scindicus* Henr. from Emirates together with one commercial species: rhodes grass (*Chloris gayana* Kunth). These were grown under controlled environment of a green house at the Arid Land Research Center, Tottori University during 2007-2008. The four grasses were sown in PVC pots 22 cm-diameter and 110 cm height filled with sandy soil to 100 cm depth. The pots received 2.4 g fertilizer containing NPK (13:13:16) plus 1.6 g micronutrients and 4.0 g Ca Hydroxide (for soil pH) before transplanting the four grasses in July 31, 2007. There were 20 pots representing the 4 grasses and a control. The pots were placed on a metal rack 13 cm above ground in a randomized complete block design with four replications. Five of the pots were each fitted with 4 soil moisture sensors at 12.5, 37.5, 62.5 and 87.5 cm down the soil profile. The pots were irrigated daily with 500 ml tap water. On Sep 3 the pots were harvested and the plants discarded, marking the beginning of the study. The pots were then irrigated daily with 150 ml and drainage water was collected daily before irrigation. Soil moisture was monitored by taking seniors readings once a week before irrigation throughout the study. The grasses were harvested at four growth cycles, oven dried and weighed. The first harvest was made 35 days from the beginning of the study (Oct 8). At the beginning of the second growth cycle, the pots were irrigated daily with 100 ml (split 50% in morning and 50% in the afternoon). The second harvest was made when plants were 37 days old (Nov 14). At the beginning of the third growth cycle the pots were fertilized with the same fertilizers applied at the beginning of the study and the irrigation level was reduced to 50 ml daily (split between morning and afternoon) and this was continued till the end of the study. The third harvest was made when the plants were 51 days old (Jan 4, 2008). The fourth and final harvest was made when the plants were 35 days old (Feb 12). After the fourth harvest, 12 of the pots (three for each species) were cut horizontally into four strata (25 cm each), the soil washed and the roots collected and stored in sealed plastic bags containing 75% Ethanol. Additionally 4 pots, representing the four species were cut vertically and whole roots were collected the same way above. Root length was measured using Comair Root Scanner. The roots were then thoroughly washed with tap water and oven dried (80 °C), weighed, ground and stored for carbohydrates (NSC) analysis.

Both Rhodes grass and Labeid maintained the highest DM yield throughout the study (4 growth cycles) with no significant difference between them. This was matched by Dakhna in the first growth cycle only. Recovery after harvest became weak for Dakhna and Da'a starting the second growth cycle and stopped re-growth completely in the third and fourth cycles. Similarly the water use efficiency (WUE) of the species followed the same pattern of the DM yield, with no significant difference between Rhodes and Labeid or Dakhna in the first growth cycle. The differences were significant between Rhodes and Dakhna; Rhodes and Da'a in the second growth cycle. WUE could not be computed for Dakhna and Da'a in the 3rd and 4th growth cycles.

Rhodes and Labeid showed the most extensive root development in the soil profile (Figure 1), explaining their persistence and high productivity. The highest root accumulation for all grasses was found on the top and bottom strata of the profile.

Lebeid and buffel grass were the highest in total NSC in their roots over the other two grasses. Total NSC followed the same pattern of root development, being highest at the top and bottom strata. The two other species were very low in total NSC in their roots, mostly a reflection of their low DM production

rather than the percent NSC content.

1.1 Introduction

The Arabian Peninsula is considered a water scarce region. Agriculture consumes most of the water available (76%) mainly for forage production and forestation. Utilizing the adapted genetic variation of indigenous forage species, could offer some solution by identifying forages with high water use efficiency and good feed quality for livestock. Indeed some of the collected forage species in the Arabian Peninsula have proven higher dry matter yield, feed quality and water use efficiency than the traditionally grown Rhodes grass.

In the present study three indigenous grasses from the Arabian Peninsula (Emirates) namely: Labeid (*Cenchrus ciliaris),* Dakhna (*Coelachyrum piercei) and Da'a (Lasiurus scindicus)* were compared with Rhodes grass (*Chloris gayana*) for their root development, carbohydrates reserves, forage production and water use efficiency under controlled environment. Data were also collected on soil moisture depletion and water drainage under the different species.

1.2. Materials and Methods

Three indigenous grass species plus, one exotic forage (see above) were compared for their forage productivity, water use (depletion of soil profile), water use efficiency and root development under controlled irrigation treatments and environment (Air conditioned green house) at the Arid Land Research Center, Tottori University. The four grasses were sown in peat moth then transplanted into large PVC pots (110 cm height and 22 cm diameter) filled with sandy soil to 100 cm. The pots were covered (wrapped) with insulating sponge which has aluminum foil on its outer surface. There were 20 pots four of these were check (no plants) for monitoring irrigation and soil moisture. The 20 pots were arranged in a randomized block design (four grasses and a check), with four replications. The pots were placed on metal rack 13 cm above ground. Plastic pans (26 cm diameter) were placed under each pot to collect drainage water.

Fertilizers NPK (2.415 g per pot), supplying 0.314 gm N, 0.314 g P and 0.386 g K and micronutrients (1.61 g per pot) and calcium hydroxide (4.025 g per pot) were added (top dressing) before transplanting grasses on July 31, 2007.

At the beginning of the study, irrigation was applied at 500 ml on daily basis using an automatic drip irrigation system fitted with a gauge. Water depletion in the soil profile was monitored in five pots using sensors. The sensors were installed at 12.5, 37.5, 62.5 and 87.5 cm soil depth (inserted horizontally along one side of the pot). The sensors measure Soil Thermal Conductivity (W m^{-1} °C^{-1}); which later converted to volumetric water content using a calibration curve. The soil moisture was monitored once a week in the 5 pots (representing the 4 grasses and the control).. On September 3, the plants on all pots were cut to ground level and discarded, marking the beginning of the experiment. Four forage harvests were made at the end of the following growth cycles: 35, 37, 51 and 39 days. Irrigation was adjusted at the beginning of the growth cycles to 150, 100, 50 and 50 ml daily for the four cycles, respectively. In the first cycle irrigation (150 ml) was applied in the morning, while in the last three cycles it was applied in the morning and afternoon (equal amounts). Fertilizer (the same amount applied earlier) was applied again at the beginning of the second crop cycle.

1.3 Data collection

1.3.1 Irrigation, drainage and soil moisture

Irrigation was monitored on daily basis (morning and afternoon) depending on the crop growth cycle, Using three pots (control with no plants) water was collected from the dripper in each pot in a plastic jar, weighed and poured back into the same pot. Drainage water was collected on daily basis, before the morning irrigation, weighed, recorded and discarded. Total water application and total drainage was computed on weekly basis during crop growth cycles. Soil moisture recording was done once a week by recording the Thermal conductivity (W m^{-1} °C $^{-1}$) using KD2 Thermal Properties Analyzer. The readings were later on converted into volumetric water content using calibration curve. Temperature and relative humidity inside the green house were recorded (at one hour interval) throughout the experiment.

1.3.2 Dry matter (DM)

At the end of each crop growth cycle (Judged by 10% flowering of Dakhna), the plants were harvested to ground level, oven dried (80°C) weighed and discarded.

1.3.3 Roots

At the end of the fourth growth cycle, 12 pots were cut (saw) each into 4 strata (25 cm). The stratum was placed on a wire mesh (2 mm) and a jet of water was applied to wash the soil. The roots were collected and placed in sealed plastic bags containing Ethyl alcohol (75%) and the bags stored in a refrigerator. One replication (4 pots) representing the four grasses were cut vertically, soil washed and the roots collected (whole root) as described above. Root length was measured using Comair Root Length Scanner. The roots were then thoroughly washed with tap water, placed in paper bags, oven dried (80°C), weighed and stored for analysis of non structural carbohydrate (NSC). The NSC analysis was carried with the help of Dr. Hikeki Okamoto (Hokkaido Prefecture).

1.3.4 Water Use Efficiency (WUE)

The dry matter yield data and the irrigation data were used to calculate WUE in kg DM per m^{-3}

1.3.5 Data analysis

The data on DM, drainage water and WUE were analyzed as a complete block design while the data on root length, root DM and carbohydrates were analyzed as split-plot design (Steel and Torrie, 1960), using analysis of variance to evaluate statistical significance between species means and root means different strata. Computations were carried out using a statistical package of Systat Software Inc. (SigmaStat 3.5). Tukey Test was used to compare means (p=0.05)

1.4 Results

1.4.1 DM yiled

Both Rhodes grass and Labeid maintained the highest DM yield throughout the study (4 growth cycles) with no significant difference between them. This was matched by Dakhna in the first growth cycle only. Recovery after harvest became weak for Dakhna and Da'a starting the second growth cycle and stopped completely in the third and fourth cycles. With the exception of Dakhna, none of the grasses produced any flowering during the four growth cycles.

1.4.2 WUE

Similarly the water use efficiency (WUE) of the species followed the same pattern of the DM yield, with no significant difference between Rhodes and Labeid or Dakhna in the first growth cycle. However, the differences were significant between Rhodes and Dakhna; Rhodes and Da'a in the second growth cycle. WUE could not be computed for Dakhna and Da'a in the 3rd and 4th growth cycles.

1.4.3 Drainage water

The drainage water was highest under Da'a in the first growth cycle, which was significantly higher than under Labeid and Dakhna. No significant differences were recorded among the four species in the following growth cycles or when the total drainage of the 4 growth cycles was compared for the five treatments (four grasses and a control).

1.4.4 Grass roots

Both Rhodes and Labeid showed the most extensive root development in the soil profile (Figure 1). The highest root accumulation was observed at the top and bottom strata of the profile for all grasses.

1.4.5 Carbohydrates

Lebeid and buffel grass were generally higher in Non Structural Carbohydrate percentage than the other two grasses. The difference became greater over the other two grasses when the total NSC was computed (total DM X %NSC) due to the greater difference in root DM among the species. Total NSC followed the same pattern of root development, being highest at the top and bottom strata.

Figure 1. Root length in 196 days after transplant of seedlings of Rhodes grass (Cg), Da'a (Ls), Labeid (Cc) and Dakhna (Cp) into PVC cylinders (22 cm diameter) filled with sand to 1-meter depth.

Experiment 2

Growth of four grasses on clay soil with particular emphasis on forage production, water use efficiency, soil moisture depletion and persistence under frequent cutting.

2.1. Introduction

The performance of four perennial grasses (three from United Arab Emirates and one commercial variety) under experiment 1 (described above) seems very different from an earlier field experiment in United Arab Emirates. For example two of the grasses (Ls and Cp) stopped re-growth after the second growth cycle. The same grasses produced new growth each time for 40 growth cycles under the field study in Emirates. Also in the above green house study although Cc and Cg grasses remained most productive and persistent to frequent harvests, similar to their performance under field condition in Emirates, but their performance under green house was different from that under field study. These differences could be due to the soil characteristics (sandy vs. loamy), and irrigation. Under the previous field study soil was loamy and the irrigation was applied once every day compared with the green house, where the soil was sand and the irrigation was applied twice daily. In the present study (Experiment 2) the performance of the same species is compared under green house conditions using clay soil and one irrigation level.

2.2. Materials and Methods

Three indigenous grass species from Emirates plus one commercial grass variety (see Experiment 1) were compared for their forage production, water use (depletion of soil profile), water use efficiency and persistence under frequent cutting. The grasses were first sown in peat moth for two weeks then transplanted into small pots (13.2 cm at top, 9 cm diameter at bottom and 10 cm height), filled with clay soil to 9 cm height (850 g). The soil used was Tohaku soil, which has the following physical and chemical properties: Bulk density (1.19 g m-3), clay content (440 g kg-1), sand (240 g kg-1), silt (320 g kg-1), organic matter (2.88 g kg-1), pH (5.8), field capacity (0.42 cm3 cm-3). Soil nutrients content were as follows: N (53 mg kg-1), Olsen P (4.45 mg kg-1). Fertilizer (0.06 g) supplying NPK (13:13:16) was added (top dressing) before transplanting two-weeks old grass seedlings on Jan 22, 2008. The pots were arranged in a randomized complete block design, with four replications. The pots were irrigated with 140 ml (FC) every 3 days till Feb 17, when all pots were harvested marking the beginning of the study. The grasses were harvest twice during the study: after 42 day's growth cycle (Mar 30) and 39 days growth cycle (May 8). Water depletion in the soil profile was monitored using sensors and KD2 Thermal Properties Analyzer which measure Thermal conductivity (W m -1 °C -1). The sensors were placed vertically into the soil (8 cm) in the center of each pot. The sensors readings were later converted to volumetric water content as described for experiment 1.

2.3 Data collection

2.3.1 DM production

All pots were harvested in Feb 17 to 1 cm above ground marking the beginning of the first crop growth cycle. Irrigation was applied to FC (140 ml water) once every 3 days. Soil moisture recording was done on the day of irrigation (before and after irrigation). The grasses were harvested on Mar 30 and May 8 by cutting to ground level, the forage was oven dried (80○C), weighed and discarded.

2.3.2 WUE

Water use efficiency (DM kg m-3 water) was calculated from total DM yield divided by total irrigation water used in each crop growth cycle. Temperature and relative humidity inside the green house were recorded (one hour interval) throughout the experiment.

2.3.3 Data analysis

The data from experiment 2 is being analyzed for randomized complete block design

Other research and technical activities during my stay in Japan

Delivering four seminars for students and faculty at the ALRC; and participating in seminars at the Arid Land Research Center and the Faculty of Agriculture. Also participated in research program discussions of the students and faculty members of the Plant Production and Plant Ecophysiology sub-divisions

- Reviewing and editing scientific manuscripts of graduate students and researchers (different sub-divisions of ALRC and Faculty of Agriculture) for conferences and Journal publications.
- Acted as reviewer for the Journal of "Grass and Forage Science' during June 2007.
- Discharging the responsibility as the Master of Ceremony during the Plenary Meeting for Collaborative Project "Global Center of Excellence in Dryland Sciences" held at ALRC on July 28, 2007.
- Acted as a reviewer on research proposals submitted to the Arab Science and Technology Foundation during July 2007.

- Participated in a field visit to dairy and beef cattle farms in Tottori Prefecture with Veterinary Science Group (Tottori University), involving five farms in Nov. 2007. The visit included discussions with farmers on farm management for livestock.
- Delivering an invited keynote address on "rehabilitation of the war-affected rangeland in Kuwait" during a technical meeting in Geneva invited to by PPSC Technical Review Committee and Observers from Kuwait NFP, the UNCC and the Kuwait Oil Company, Geneva, 13-16 March 2008.
- Visited the United Nations University, Tokyo in April 2008 and participated in group discussion on management of natural resources under arid land environments.
- Delivered a lecture on the activities of ICARDA in the Arabian Peninsula with particular emphasis on rangeland and forage production during my visit to the United Nations University on April 2008.
- Assisted the Director General of ALRC and head administration office in matters related to collaboration with ICARDA, Aleppo, Syria.

Dr. Muhammad IRSHAD (Soil Science)

October 2007 – July 2008

Water Management Department, Government of North Western Frontier Province, Pakistan

Title: Research on the improvement of sodic soil using organic amendment

Research activities

The focus of my research is to monitor nutrient dynamics in the soil-plant system under saline and water deficit conditions. Mitigating the adverse effects of marginal quality waters on crops and soils using waste amendment is also my research target. Major research activities included the publication of several articles in collaboration with other researchers in the field of sustainable management of agriculture in arid land as depicted from the following list of publications. Reviewing and editing of scientific documents of students and researchers in the ALRC and Faculty of Agriculture were part of major activities this time. Other activities included growth-chamber experiments together with Dr. Ould Ahmed and Prof. M. Inoue, open seminars, overseas conferences and participation in various lectures and seminars.

Open seminars delivered at ALRC

a. Integrated Management Strategies for the Development of Agriculture in Dry Areas
b. Management Options of Marginal Quality Waters for Irrigation in Arid and Semi-arid Areas
c. Remediation Challenge of Salinity-induced Land Degradation in the Developing Countries
d. Importance of Soil Organic Matter for Sustainable Agriculture

Research summary

1) Interrelation of irrigation frequency and manuring on the growth and water use efficiency of wheat under arid condition

Good water management along with appropriate soil amendments is necessary for sustainable crop production. An experiment was conducted to evaluate the response of wheat (*Triticum aestivum* L.) to manuring and irrigation frequency in sand dune soil under growth chamber conditions for eight weeks. Manure was applied at the rate of 0 (M0), 10 (M1) and 20 Mg ha^{-1} (M2) along with daily, 2 or 4 days

irrigation frequencies denoted as W1, W2 and W3, respectively. Irrespective of the manure the daily irrigation gave 18 and 25% higher biomass yield as compared to W2 and W3, respectively. Application of M1 and M2 enhanced dry matter yield by 57 and 107%, respectively whereas the number of tillers were increased by 69 and 117%, respectively as compared to unamended soil. The cumulative evapotranspiration (ET) was slightly increased in M1 whereas in M2 it was similar to M0 in spite of the higher plant biomass. Thus, the manured soil saved higher magnitude of water than control soil. The water use efficiency (WUE) of crop under M1 and M2 treatments was increased by 42 and 115%, respectively than M0. For both ET and WUE, irrigation frequencies were varied as W1 > W2 > W3. Photosynthetic rate (P_N), transpiration rate and stomatal conductance (g_s) apparently decreased with longer irrigation period. However, plants maintained dark green color in W3. As expected the cumulative ET was positively associated with P_N, g_s and transpiration rate.

2) Bioavailability of plant nutrient in manured soils irrigated with saline water

The experiment was carried out under growth chamber conditions where alfalfa plants were irrigated every day or 2nd day regularly either with tap water or saline water (ECw: 2 dS m^{-1}). Plants were grown for 2 months. Poultry and cow manures were applied at the rate of 20 t ha^{-1}. This study showed a significant interaction of saline water and manure on the dry matter production of alfalfa. A retarded plant growth was noticed with saline water as well as deficit irrigation. Manure treatments substantially enhanced plant biomass and the growth was varied in the order of cow manure > poultry manure > control. The treated soil samples are being analyzed for bioavailability of essential plant nutrients. Statistical regression will be determined between the nutrient solubility and biomass production in manured soils under the effect of saline or non-saline waters.

Dr. Richard James THOMAS (Natural Resources Management)

December 2007 – May 2008

International Center for Agricultural Research in the Dry Areas, Syria

Title: Review of how an integrated approach to natural resources management can contribute to combating desertification

Summary of activities

- Development of a challenge program research proposal
- Attendance at CGIAR Annual General meeting in Beijing Dec 1-5 to present a luncheon seminar on the Oasis consortium to combat desertification
- Attendance at Oasis consortium proposal writing group held at the UNCCD, Bonn, Germany Jan 15-23, 2008.
- Attendance at the CGIAR Science Council meeting on the Oasis and other Challenge Programs Jan 29-Feb 6, 2008
- Attendance at second meeting of Oasis writing group at UNCCD, Bonn, Germany, March 10-16, 2008.
- The output of these meetings is a research proposal to be considered as a global challenge program for funding by the CGIAR and others in May 2008.

Joint program in M.Sc.'s degree Integrated Land Management in drylands

This degree program is a joint venture between UNU, IRA and INAT in Tunisia, CAREERI in China, ICARDA and recently ALRC, Tottori. Five lectures have been prepared for the 4 M.Sc. students who will attend the course at ICARDA for two weeks starting March 26, 2008.

In addition a planning meeting was held at ALRC on March 5 with representatives from ALRC, Tottori University, UNU and ICARDA to plan the next phase of the M.Sc. program that will include Japanese students.

Revision of manuscripts from ALRC staff

Scientific and English language editing of five manuscripts from ALRC staff were completed.

Seminar presentations in Tottori University

- What is desertification and what drives it? April 22, 2008.
- Te international context and conceptual frameworks for desertification, April 28, 2008
- An integrated approach to Natural Resources Management, May 12, 2008.
- Case studies of the INRM approach, May 19, 2008.
- Land degradation and climate change, May 26, 2008.

Other seminars

Research for dryland development. Presented at the hearing of Working group C of the European Parliament on 'desertification- socioeconomic, agricultural and forestry impacts and their political consequences, May 15, 2008 European Parliament, Brussels, Belgium

Dr. Izzat Shidahmed Ali TAHIR (Plant Breeding)

April 2008 – March 2009

Agricultural Research Corporation, Wad Medani, Sudan

Title: Molecular, biochemical and physiological assessments of genetic diversity in sesame germplasm from different growing regions in Sudan

Summary of research and other related activities

My research and other academic activities included a field experiment, two laboratory experiments on sesame and wheat, delivering four open seminars, attending an international conference, participation in workshops, seminars and other scientific activities at ALRC and Tottori University, editorial work on considerable numbers of scientific documents including manuscripts for peer-reviewed journals, conferences and student thesis.

Research activities

Sesame (*Sesamum indicum* L. Pedaliaceae) is one of the oldest oil seed crops known to humans for its high quality seed oil. Sudan is one of the most important sesame producers and exporters in the world and it has been considered one of the areas with great variability in cultivated sesame. The sesame breeding program aims at developing cultivars with high and stable yields under biotic and abiotic conditions such as drought, water logging, lodging, seed shattering, pests and diseases, and possessing good seed quality and composition. To achieve these goals, genetic variations bearing various desirable traits are of paramount importance. The success of a crop-improvement program largely depends on the availability and

knowledge of the genetic resources in a germplasm collection. A considerable number of sesame accessions have been collected from different sesame-producing regions in Sudan. Exploitation of genetic diversity is essential to develop new crop varieties with increased yield, better quality and improved resistance to biotic and abiotic stresses. Despite the high economic value of sesame worldwide, only few reports are available on the use of molecular markers in genetic diversity analysis of sesame for traits important to breeders, geneticists, farmers and for conservation purposes.

Beside its considerable economic value for both farmers and the country, sesame provide a potential alternative rotational crop in the vast rainfed areas of Sudan where sorghum mono-cropping system is threatening the whole area through the continuous build-up of *Striga,* a devastating parasitic weed. This is anticipated to safe large areas from being out-of-production and hence contribute in compacting desertification in these areas.

On the other hand, wheat (*Triticum aestivum* L.) is an important food crop in Sudan and its annual consumption rate is growing rapidly. Wheat production in Sudan is constrained by many biotic and abiotic factors among which heat and moisture stresses remain the major limiting factors for high productivity. A number of varieties were released which are adapted to the hot and dry environment of Sudan. The knowledge of genetic bases of this adaptation to such environment among these varieties could be useful for future wheat improvement in the unique condition of Sudan.

Objectives

A) Sesame

This study aimed to investigate the sesame diversity by analyzing sesame populations collected from different geographic regions of Sudan.

1- Quantitative characterization and purification of the sesame accessions used in this research.
2- Structural characterization at the molecular level using microsatellites or simple sequence repeats (SSRs).
3- Selection of lines possessing useful traits to be included in the breeding program for improvement of different desired traits.

B) Wheat

The objectives of this study were to examine the genetic diversity among wheat varieties released over the last 50 years in Sudan, to quantify the effect of a half century of wheat breeding on genetic diversity and variability and to provide a rapid and accurate identification matrix of the bread wheat germplasm in Sudan.

Experiment 1

Quantitative characterization and purification of the sesame accessions collected from Sudan

Ninety nine sesame accessions collected from different growing regions in Sudan were quantitatively characterized and purified by seed color, shape, texture, capsule shape, seed retention ability, photoperiodic sensitivity, etc. The original set of accessions was preliminarily purified by seed shape, color and texture. The original and purified accessions were grown under the vinyl house condition in the field of ALRC along with 34 additional accessions from 10 different Asian countries. These 34 accessions comprising 13 from Japan, four from China, three from South Korea, two from India, Pakistan, Bangladesh, Myanmar, Seri Lanka, Nepal and Thailand, were kindly provided by Prof. Masumi Katsuta and Dr. Naoki Ohgata of the National Institute of Crop Sciences, Tsukuba, Japan. These accessions were planted in 240 plots

arranged in an augmented design. Each accession (except for those with few seeds) was grown in a 0.8m row with 8 holes 10 cm apart. All cultural practices including fertilization with NPK fertilizers were kept at optimum levels. Data were collected on early vigor, flowering time, growth habit, capsule shape and opening manner, etc. At maturity, capsules from at least three plants were harvested separately and seeds were collected manually and their color, shape, roughness were scored.

Experiment 2

Molecular characterization of sesame accessions using microsatellites or simple sequence repeats (SSRs).

A total of 190 accessions including the original collections, the purified lines, breeding materials from Sudan and the 34 accession from the ten Asian countries were used in this study. Apical young leaves from 6 plants per accession were collected and used for DNA extraction. Leaves were ground in liquid nitrogen and the DNA was extracted from100 mg of the tissue powder using DNeasy Mini Plant Kit. Ten microsatellite primers were used for studying the level of diversity among these lines. Primers were labeled with fluorescent dyes of different colors at the 5' end of the forward primer. PCR was carried out using Qiagen multiplex PCR kit following the manufacturer manual except for the annealing temperature which was optimized for each primer. Multiplex PCR was carried out with some primer pairs after testing their suitability in multiplex reactions. PCR products were analyzed using capillary sequencer. Polymorphism was analyzed manually.

Experiment 3

A set of 23 wheat varieties released over the last 50 years in Sudan were analyzed for their genetic variability using SSR markers. DNA was extracted from 100 mg of two-week old seedlings using DNeasy Mini Plant kit. Seventeen SSR markers were used covering the whole genome by at least one allele per each chromosome. PCR was carried out using Qiagen multiplex PCR kit following the manufacturer manual. Some primer pairs were designed for multiplex PCR after testing their suitability in multiplex reactions. PCR products were separated by Agarose gel electrophoresis and polymorphic bands were visualized using ethiduim bromide.

Results:

Experiment 1

An immense genetic variability was observed among the sesame accession in terms of photoperiodic sensitivity as indicated by the flowering time. Flowering times differed from less than 35 days in some accession from Asia to more than 90 days in some Sudanese accession. Most of the accessions from Sudan showed long-day sensitivity as indicated by the prolonged vegetative growth. The original 99 accessions from Sudan were purified to more than 190 accessions based on seed color, texture and shape, capsule type and other quantitative characters. This will form the base of core collection for Sesame in Sudan.

Experiment 2

Preliminary results of this experiment indicated high level of polymorphism among sesame accessions from Sudan as well as that from Asia based on the SSR markers used in this study. SSR markers were efficient in estimating inter and intra-specific genetic diversity sesame and these molecular marker could differentiate the local land races and varieties collected from different locations. Genetic variability was observed among lines selected from within a single accession. However, some level of similarity was found

between accessions collected from different geographical zones.

Experiment 3

The SSR markers used in this study revealed different levels of variability among the set of wheat varieties released in Sudan during the last 50 years. It was found that some of the old cultivars shared a certain level of similarity as revealed by the SSR marker used in this study. Thereafter, the crop improvement modified the genetic make-up of the recent cultivars which showed differences from that of old cultivars as well as the standard wheat line Chinese Spring. However, some level of similarity was observed among the recently released cultivars which might resulted from the intensive selection for heat tolerance as well as the narrowing-down of genetic-bases observed recently in many areas of the world.

Seminars

The following open seminars have been delivered during my stay at ALRC:

1. Wheat Research and Production in Stressed Environments: A Case Study from Sudan
2. Methods for Wheat Improvement in Stressed Environments
3. Sesame: A Potential Rotational Crop in the Mono-cropping Rainfed Agriculture System of Sudan
4. Utilization of Genetic Diversity in Sesame for the Crop Genetic Improvement

Other activities

In addition to actively participating in the discussion of master and doctoral student's research proposals of the ecophysiology sub-division, I carried out editorial works on considerable number of scientific documents including manuscripts for peer-reviewed journals, conferences, workshops and student thesis. I also participated in some workshops and meetings held at ALRC and Tottori University.

Dr. Shiping WANG (Pomology)

June 2008 – March 2009

School of Agriculture and Biology, Shanghai Jiaotong University, China

Title: Development of water-saving irrigation technology for grapevine cultivation in arid areas

Summary

Grapevine is widely planted in arid areas, but vineyards in these areas are facing the problems such as large evaporation, serious water leakage of irrigation, which causes waste of precious water resource. Current year (from 1st June 2008 to 31st March 2009), we carried out 4 experiments about grapevine water-saving techniques in dry areas as following: Experiment 1, The influence of irrigation style and mulching with rice straw on vine growth and berry development of grapevine cultured in sandy land; Experiment 2, Study on critical value of the soil water potential for irrigation-beginning in berry growth stage of grapevines; Experiment 3 Study on critical value of the soil water potential for irrigation-beginning in berry maturity stage of grapevines; Experiment 4, Development of self-watering technique for container-grown grapevine base on capillary wicking water cultivation. In Experiment 1, through the study on the irrigation mode using weighing lysimeter and mulching with rice straw, we can see that the treatment of Sub-surface with Rice-straw mulching (SIRM) presented better shoot growth and berry development, higher soluble total solute solid content (TSS), better coloring and higher yield, compared with other treatments such as Sub-surface irrigation with Rice-straw mulching (SSIM),

Sub-surface irrigation (SSI) and surface irrigation (SI). Results of Experiment 2 showed that during the berry growth stage the critical value of soil water potential was around -50mbar for irrigation-beginning. For Experiment 3, by testing the daily changes of photosynthetic rate, stomata conductance and berry diameters in the process of water potential decreasing, we found that during the berry maturity stage the critical value of soil water potential was around -140mbar for `irrigation-beginning. Results of Experiment 4 showed that capillary wicking water cultivation (CWWC) could meet the water demand of grapevine growth and berry development and is proved to be a grapevine cultural technique as water-saving, easy-carrying, environmental friendly and with a promise future in the arid areas.

Research results

Experiment 1

The influence of irrigation style and mulching with rice straw on vine growth and berry development of grapevine cultured in sandy land, through the study on the irrigation mode using weighing lysimeter and mulching with rice straw, we can see that the treatment of Sub-surface with Rice-straw mulching (SIRM) presented better shoot growth and berry development, higher soluble total solute solute content (TSS), better coloring and higher yield, compared with other treatments such as Sub-surface irrigation with Rice-straw mulching (SSIM), Sub-surface irrigation (SSI) and surface irrigation (SI).

Experiment 2

Determination of the threshold of soil water potential (ψ) at which irrigation should be started in plants is important for efficient use of water in drylands where water is scarce. This study attempted to determine such threshold for scheduling irrigation during the berry-growth stage of grapevine (*Vitis vinifera* ×*Vitis labrusca*) using berry diameter as an indicator of water stress. After irrigation, grapevine was allowed to experience decreasing ψ monitored by tensiometers. The instantaneous variations in the berry diameter were measured by photogrammetry simultaneously. Photosynthesis was also measured. Berry diameter increased at night and decreased in the day, and showed sensitivity to developing soil moisture stress. It increased rapidly after irrigation till ψ became $\underline{=}$30 mbar. In the ψ range of $\underline{=}$30 mbar to $\underline{=}$54 mbar, the growth rate decreased, and as ψ decreased beyond $\underline{=}$54 mbar, the berry started shrinking and the shrinkage showed a strong linear relationship with decreasing ψ. In contrast, photosynthesis remained unaffected by decreasing ψ until it became $\underline{=}$105.4 mbar beyond which photosynthesis decreased significantly. Thus, berry diameter was a better indicator than photosynthesis of developing moisture stress and –54 mbar should be considered as the threshold ψ for scheduling irrigation during the berry-growth stage in grapevines.

Experiment 3

Many studies showed that for fruit trees, water stress would stimulate the transportation and accumulation of photosynthetic products in fruits from leaves. However, overdoing water deficit may decrease the photosynthesis rate and cause the decrease of sugar accumulation in fruit. In this experiment, we implement water stress on grapevine in berry maturity stage, test the daily changes of photosynthetic rate, stomata conductance, and berry diameters and together with the changes of photosynthetic products (^{13}C marking) transported into the berry during the process of water potential decreasing. The critical value of soil water potential was discussed during the berry maturity stage. 2-year-old “Pione” grapevines were planted in 32L pots and were moved into growth chamber in berry maturity stage (80 days after anthesis).

Root zone soil water potential, berry diameter (mensurated by photogrammetry) and photosynthesis rate were tested every 2 hours after fully irrigation. Feed $^{13}CO_2$ to leaves for 1 hour when the soil water potential in root zone reached to -9.3mbar, -52.2mbar, -91.7mbar, -146.7mbar, -218.7mbar respectively. Sample berries at 2 hour and 8 hours after each labeling respectively and test the content of ^{13}C. The results showed that before the soil water potential decreased to -140mbar, the daily changes of photosynthesis rate and stomata conductance were nearly in the same trend as increased in the morning and decreased in the afternoon. However, when the soil water potential decreased below -140mbar, both photosynthesis rate and stomata conductance decreased sharply and could not recover to normal again. Meanwhile, the amount of ^{13}C that transported into berries from leaves declined rapidly either. We can make conclusion from the above results that -140 mbar should be considered as the threshold of soil water potential (ψ) for scheduling irrigation during the berry-maturity stage in grapevines.

Experiment 4

Self-watering containers represent a relatively new gardening concept in annual herbaceous plants, including vegetables and flowers. However, little information about self-watering technique is available for perennial fruit trees since the relative large root system and canopy, which usually gown in drylands, such as grapevine. In this study, we designed a new self-watering system for container-grown grapevine according to the principle of capillary wicking water, and investigated the feasibility for grape production. This system consisted of a container with two holes on the wall, which is placed over a nutrient solution reservoir. Two nonwoven fabric sheets covered with polyester across the holes on the wall, respectively. A stock tank provided the nutrient solution for the above reservoir through plastic tube and the volume of water was remained a stable level. The bottom end of sheets immersed into the nutrient solution and the upper end of sheet was set around the root system. Nutrient-enriched water is wicked up from the reservoir into the potting soil by the nonwoven fabric sheets for grapevine growth. In 2008, two-year-old potted 'Pione' grapevines with two branches were transplanted into the above mentioned containers with 22 L volume and defoliated in middle September. After treatment with hydrogen cyanamide, the self-watering grapevines were placed in growth chambers. The full bloom is 15 October, and version stage started from 14 December. The mean length of primary shoot and lateral shoot were 142.7cm and 39.8cm, respectively. Berries with good color were harvested at 10 January 2009. Mean berry weight and total soluble solution (Brix) were 9.1g and 24.5, respectively. The amounts of nutrients uptake by the grapevine for N, P, K, Ca were 5.4g, 2.5g, 8.5g, and 3.5g, respectively. The results showed that besides satisfied yield and good berry quality can be obtained, the self-watering system also can increase water and fertilizer use efficiency, reduce soil surface transpiration, and avoid the environment contaminated by the lead compared with the irrigation for conventional container.

Dr. Mohan Chandra SAXENA (Arid Land Ecophysiology)

October 2008 – September 2009

International Center for Agricultural Research in the Dry Areas, Syria

Title: Response of *Jatropha curcas* to salinity and osmotic stress

Summary of the research activity

Increasing demand and rising prices of energy and the growing threat to environment with the use of fossil fuel have necessitated the search for green renewable sources of energy. In the face of global

environmental change, the fuel needed is that which has low carbon footprint. Oil-bearing shrubs and trees such as *Jatropha curcas L. (Euphorbiaceae)* and *Pongamia pinnata* (L.) Pierre (*Papilionoideae*, the tribe *Millettieae)* are important in this regard, particularly because they are reported to be able to grow on lands that are marginal and degraded so that their cultivation would not compete with important food, feed and fiber crops for land. However, the information on the effect of moisture and salinity stress and quality of irrigation water on germination and early seedling growth is rather limited. Such information would be essential to grow these species in arid and semiarid areas where salinity is common, water is scarce and the quality of irrigation water is often marginal. Hence, following experiments have been conducted / are being conducted under controlled environmental conditions to develop some of this information:

(a) Experiment 1: Effect of boron concentration in irrigation water on the germination of *Jatropha curcas* provenance from Tanzania and Kenya.

(b) Experiment 2: Response of *Jatopha curcas* seedlings to irrigation with saline water.

(c) Experiment 3: Response of *Jatropha curcas* seedlings to irrigation with water of different boron concentrations.

(d) Experiment 4: Response of *Pongamia pinnata* seedlings to irrigation with saline water and water with 6 mg boron per liter.

Results of the experiments

A brief description of the experiments being conducted and results obtained so far is given below:

Experiment 1

Effect of boron concentration in irrigation water on the germination of *Jatropha curcas* provenance from Tanzania and Kenya.

High concentration of boron (B) in irrigation water often limits plant growth. What is the safe level of B in irrigation water at which the *Jatropha curcas* seeds could germinate is not known. Hence, the effect of six concentrations of boron (0, 1, 2, 3, 4, and 5 mg B per liter of solution) on the germination of surface sterilized seeds of *Jatropha curcas* accession from Tanzania was investigated using filter paper-lined Petri dishes in a germinator at 25^{o} C. Twelve seeds were used for each treatment. The germination percentage was not much affected by the treatment, the values being 66.6%, 75.0%, 75%, 57.5%, 57.5% 57.5% and 75%, respectively when the B content in the water was 0, 1, 2, 3, 4, and 5 mg per liter, respectively.

To test whether the seeds could germinate at even higher B content in the water used for germination, another study was conducted in which the germination of seeds of two different provenances of *Jatropha curcas* (one from Tanzania and other from Kenya) was evaluated at four concentrations of boron (0, 5, 10 and 15 mg B per liter of solution) using the same procedure as above. Results showed that germination could occur even at the highest level of boron in both the provenances.

The results of this study shows that *Jatropha curcas* seeds could germinate in water that might contain as high boron content as 15 mg per liter. This is a boron concentration several times higher than the one recommended as safe for crop cultivation.

Experiment 2

Response of *Jatopha curcas* seedlings to irrigation with saline water.

The seedling establishment stage is very critical for getting good field stand of *Jatopha curcas* and irrigation becomes necessary to get the seedlings established in the dry areas. The quality of irrigation

water in many dry areas is also poor, containing high levels of salinity. The objective of this experiment is to examine the effect of saline water irrigation on the growth and some physiological parameters of one and half month old seedlings of Tanzanian and Kenyan provenances of *Jatropha curcas* to generate information that might help in designing irrigation strategies for good establishment of the plants. The experiment is being conducted in glass house, with natural light conditions and a temperature regime of 25^{o} C and a relative humidity of about 30%, using 1/5000 a Wagner pots filled with 5 kg of dune sand with free drainage. The treatments include irrigation every 4-5 days with water of three different levels of salinity created by dissolving NaCl in tap water (tap water, 100 mM and 200mM NaCl). The EC values are 0.10, 10.5, and 19.6 dSm^{-1}, respectively. The water lost per pot by evapotranspiration is determined by weighing the pots and at the time of each irrigation the moisture content is brought back to full water holding capacity. There are three replications, and pots are organized in a randomized block design. The differential treatments were started on 2 March 2009.

The plants showed drooping of leaves immediately after application of saline water of highest concentration (EC=19.6 dSm^{-1}) for the first time, but showed recovery later. However after the further cycles of irrigation they stated showing the drying of lower leaves, starting from the margins. No such effect was observed in case of the treatment with lower level of salinity (EC=10.5dSm^{-1}). The Tanzanian provenance appears to be more sensitive than the Kenyan one to salinity. The evapotranspiration decreased as the salinity level increased. Measurement of photosynthesis, transpiration and stomatal conductance after two cycles of saline water irrigation showed that these parameters were severely decreased by salinity, and almost no photosynthesis occurred at the highest level of salinity. Possibility of recovery of plants by giving them irrigation with tap water will be examined.

In an ancillary experiment, two plants of Tanzanian provenance and four plants of Kenyan provenance, raised in similar style as the plants for above experiment, were irrigated with ten times diluted sea water (one part sea water, 9 parts of tap water on volume basis) to explore the possibility of using diluted sea water for irrigation to establish *Jatropha curcas.* The EC of the diluted sea water was 5.56 dSm^{-1}. The treatment was started on 11 March 2009. Till 23 March, by which time plants had received two cycles of irrigation, plants showed no symptoms of any toxicity.

Experiment 3

Response of *Jatropha curcas* seedlings to irrigation with water of different boron concentrations.

One and half month old seedlings of Tanzanian provenance of *Jatropha curcas,* growing on 5.0 kg dune sand in 1/5000 a Wagner pots with free drainage, were irrigated with water containing four levels of boron (0, 2, 4, and 6 mg B per liter of irrigation water prepared by using tap water and boric acid) at nearly weekly interval. At each time, the soil moisture was brought back to water holding capacity. There were three replications and the pots were organized in a randomized block design in the glass house which had a fixed temperature of 25^{o} C and about 30% relative humidity. Plants experienced natural light. The treatments were started on 2 March 2009.

Measurement of crop evapotranspiration till 23 March 2009 showed that there was no significant difference between the treatments. Plants also showed no symptoms of B toxicity till this date. Measurement of photosynthesis on 18 March by which time the plants had received three cycles of irrigation showed no difference between the treatments. Results suggest good tolerance of boron levels up to 6mg per liter by the Tanzanian *Jatropha curcas* provenance.

Experiment 4

Response of *Pongamia pinnata* seedlings to irrigation with saline water and water with 6 mg boron per liter.

Seeds of an Indian cultivar of *Pongamia pinnata* were sown on 16 October 2008 in small plastic bags containing a sand+organic matter mixture (60%:40% on volume basis) and irrigated with tap water. They germinated by 31 October 2008. When they were 20 days old, they were transplanted in 1/5000 a Wagner pots containing same potting medium as used for germination. They were fertilized with lime at 100kg per 10a and a granular inorganic fertilizer (15-15-15 N, P, K) at 10 kg per 10a. Plants got affected by spider mite. Hence they were sprayed with appropriate mite controlling pesticide.

On 2 March 2009, the treatment with irrigation water of three levels of salinity (0.12, 5.46 and 10.54 dSm^{-1}), prepared by dissolving NaCl in tap water, was started. There were three replications, and the pots were arranged in randomized block design on a table in the glass house (biohazard room) having more or less a constant temperature of 25^{o} C and , 30% relative humidity and natural light. Irrigation was given every 5-7 days to bring the soil moisture to water holding capacity of the soil medium. No effect of salinity in irrigation water was apparent on the crop growth till 23 March 2009, by which time plants had received six cycles of irrigation. The crop evapotranspiration decreased as the salinity level increased, but the decrease was not as conspicuous as in case of *Jatropha curcas*. The photosynthesis, transpiration, stomatal conductance and the growth of the plants will be monitored in the future, besides the measurement of evapotranspiration.

Because of limited number of plants available, two plants were also subjected to irrigation with water containing 6mg boron per liter of irrigation water. The treatment started on 16 March 2009. Till 23 March, three cycles of irrigation were completed. There was no adverse affect apparent till that date.

(4) Project Researchers

Dr. Hisashi TOMEMORI (Protected Cultivation)

The Protected Cultivation Subdivision conducts research on the sustainable cultivation method in the dry lands. Particular efforts are being made to improve the method of cultivation of physic nut (*Jatropha curcas* L.) which is the representative biodiesel fuel plant in dry land.

The main research topics in the fiscal year were as follows:

- Study on the irrigating method for the root systems of physic nut
- Low-temperature tolerance of physic nut
- Pruning method for physic nut
- Supply of phosphoric acid using porous glass materials

Research grants:

- Ebara, Hatakeyama Foundation “Growth Promotion for trees with phosphate adsorbed porous glass materials”

Dr. Takayuki KAWAI (Groundwater Hydrology)

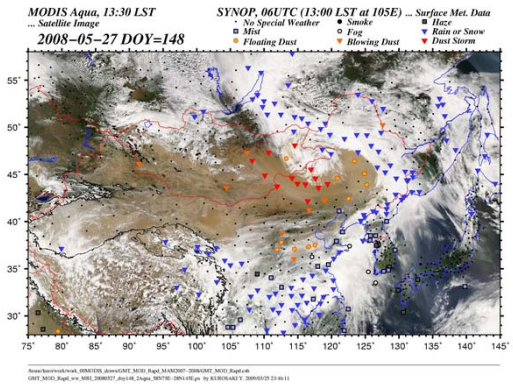
To develop new groundwater inquiry technology in sandy area, various hydrological phenomena were researched. The subject of research was classified the following two:

1. Physical inquiry of groundwater flow path
2. Influence of geological condition on percolation

Concretely, the interrelation of geological features, the groundwater level, and the groundwater volumetric flow was investigated by groundwater flow sound; Generic name of sound wave that originated when free groundwater flowed. Moreover, the influence of the lamina structure; It is a sediment feature of sand dune, on percolation was examined.

The main fellowship grant is the discretion of the Tottori university's president and Japan Society of the Promotion of Science Grants-in-Aid for Scientific Research (C), 2008-2010 (Project Leader: Kamichika M.). Moreover, four announcements were done at the domestic and foreign academic society concerning arid land and sand dune.

Dr. Yasunori Kurosaki (Dust Climatology)



The Dust Climatology Subdivision has two subjects: (1) monitoring of the spatial and temporal dust distribution; (2) clarification of the relationship among wind, land surface conditions (e.g., soil size distribution, soil moisture, soil freezing, vegetation distribution, cultivation, grazing), and dust emission.

On the subject (1), researches are conducted mainly using MODIS true color images (hereafter MODIS image) and SYNOP report, which is meteorological data observed at meteorological observatories. In this fiscal year, I built up a system which creates MODIS images resampled on geographical (Latitude/Longitude) coordinate in East Asia and I archived the images since 2001. The figure is an example of the MODIS images which present weathers obtained from SYNOP report are plotted on. Moreover I started building a system, which creates the MODIS images on near real-time. Although this system is still not completely automatic, the images are already open on http://www.alrc.tottori-u.ac.jp/staff301/ (password required), and these are utilized for observations and discussion on dust emission and transport in GCOE Global Environment Group (Leader: Prof. Shinoda Masato) and dust researchers of universities and research institutes.

On the subject (2), I aim to clarify the relationship between land surface conditions and threshold speeds, which is the wind speed initiating dust emission. Here threshold speeds are estimated from wind speed and dust emission data, which can be obtained from present weather data etc. Comprehension of characteristics and qualities of meteorological and land surface data is important in this subject. In this fiscal year, I conducted a survey on soil, vegetation and soil moisture in the field trip to Mongolia, interviews about observation at meteorological observatories in this trip, and information gathering of meteorological and land surface data in domestic conferences and workshops. I also made presentations about the relationship

between land surface conditions and threshold speed and its seasonal variation.

Dr. Shigeoki MORITANI (Desert Revegetation Science)

Soil degradation resulting from accelerated water and wind-induced erosion is a serious problem, and it is likely to remain so during throughout this century. The detachment and transport of soil particles degrade the fertility of agricultural land and reduce its productivity. Soil erosion causes siltation of ditches, and runoff material from eroding surfaces is a major contributor of non-point-source pollutants that accumulate in surface water bodies. Many of the particles involved in soil erosion processes, such as raindrops, soil aggregates, and sediment, have characteristic dimensions on the millimeter scale. The modeling and quantification of such processes require detailed measurements of the physical, chemical, and biological properties of soils (Soil Conservation Service, 1976). However, these measurements are too slow, tedious, and expensive for routine or regular monitoring.

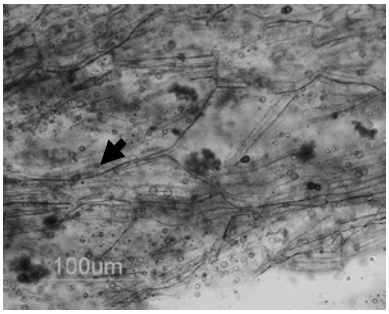
Analytical photogrammetry has often been used in geomorphological studies of gully and rill formation. Unfortunately, applying this method to monitor sheet erosion is rather limited, because of the inaccuracy of the photogrammetry. In a dryland environment, however, soil erosion manifests itself as either sheet or gully erosion. Sheet erosion predominates in upland areas, where relatively thin soils occur over bedrock, whereas gully erosion is confined to areas of weakly consolidated rocks and thin soils. The main research topics in the fiscal year was to generate digital elevation models (DEMs) having high spatial and temporal resolution from soil surfaces that developed sheet erosion. Digital photogrammetry was used to measure erosion rates and for evolution of a sheet erosion under laboratory simulated conditions.

Dr. Erdenebayar MUNKHTSETSEG (Agricultural Meteorology)

Interactions between vegetation activity and land surface processes

Dr. Takeshi TANIGUCHI (Microbial Ecology)

I aim to reveal the ecological characteristics of symbiotic microorganisms in semi-arid lands and to apply the microorganisms for restoration of semi-arid lands. Nodule bacteria and mycorrhizal fungi are major symbiotic microorganisms of plants, and I mainly study on the mycorrhizal fungi.



Arbuscular mycorrhizal fungi
in the root of *Tamarix*

As overseas activities of the fiscal year, the symbiotic relationships between mycorrhizal fungi and various plants, containing *Tamarix austromongolica*, living in Inner Mongolia, China were examined in June. In September, mycorrhizal symbiosis of *Sabia vulgaris* were also examined at Mu-us desert located in Inner Mongolia, China.

In addition, the effects of mycorrhizal fungi on the improvement of salt stress tolerance of *Pinus sylvestris*, which is used for restoration in China, were also studied using facilities of the Arid Land Research Center.

Dr. Yunxiang CHENG (Plant Ecology)

The understanding of vegetation responses to livestock grazing has become an important issue in rangeland management. This study was focused on changes in species composition and environmental variables along a grazing gradient. Overseas research activities during the fiscal year were performed in

Mongolia. Vegetation researches along a grazing gradient were carried out in three different ecological zones: the steppe, desert-steppe and desert.

Research grants (except for) in the fiscal year include:

1. Global COE program, Global Environment group
2. Japan Society of the Promotion of Science Grants-in-Aid for Scientific Research (B), 2008-2010 (Project Leader: K. Takura, University of Tsukuba)
3. Japan Society of the Promotion of Science Grants-in-Aid for Scientific Research (B), 2007-2010 (Project Leader: T. Nakamura, University of Tsukuba)

Dr. Andry Henintsoa RAVOLONANTENAINA (Soil Management)

Soil, water and nutrients are the basic resources in agriculture for food and environmental security. The rapid decline in quality and quantity of global natural resources due to degradation and uncontrolled resource consumption in many countries, especially the developing countries, is a threat to sustainable agriculture and environmental security. Adoption of a more holistic approach with a strong focus on the integration of soil-plant-water-nutrient by maintaining an appropriate balance between the use and conservation of soil nutrients and water resources for sustainable agricultural and environmental security is a new challenge.

Soil Management Subdivision conducts research on the maintaining a proper supply of organic matter in the soil, proper nutrient and water supplies, controlling soil pollution, and controlling erosion in dry land regions. Improved agricultural practices have great potential to increase the amount of carbon sequestered and water retention in cropland soils. By the adoption of this management practice, agriculture contributes not only to soil conservation and water quality goals, but also for enhancing the amount of soil organic carbon in the soil and to mitigate CO_2 emission effects on climate change. The main research topics in the fiscal year were as follows:

- Clarifying the effectiveness of organic matter content on soil aggregate stability, soil hydraulic properties, and erosion under different simulated rainfall intensities.
- Determining the effect of two hydrophilic polymers derived from industrial waste on the water holding capacity and hydraulic conductivity of sandy soil, as affected by soil temperature and water quality.

Dr. Tadaomi SAITO (Soil Hydrology)

Studies on monitoring, evaluation and prediction of soil water and solute movement and interaction with the ecosystems in arid lands were conducted. Two main field and laboratory studies were introduced as follows;

・Study on a water harvesting system in the Loess Plateau, China

For afforestation on steep slopes in the Loess Plateau, a small scale water harvesting system, called “fish-scale-pit (FSP)”, is commonly used to reduce erosion and increase soil water storage. To evaluate the effectiveness of FSP

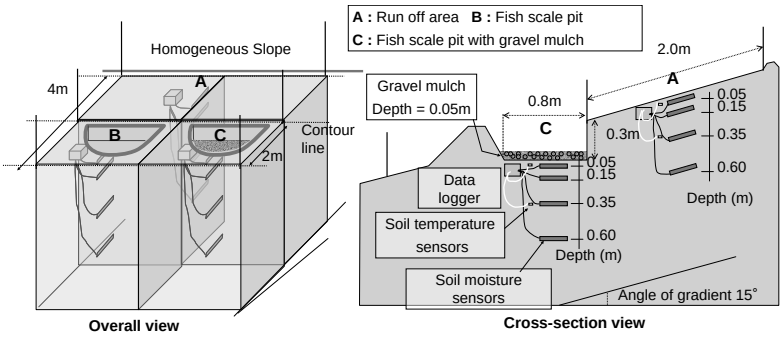


Fig.1 Schematic diagram of the experimental site

systems, I have conducted two types of investigations in the north of Loess Plateau: i) water balance analysis and modeling of FSPs in an experimental site using various monitoring devices (Fig.1) and ii) investigations on soil, topography and tree growth in a field afforestation site (Fig.2).

・Clarification of the theoretical background and development of the calibration method of temperature and salinity effects on dielectric soil moisture probes

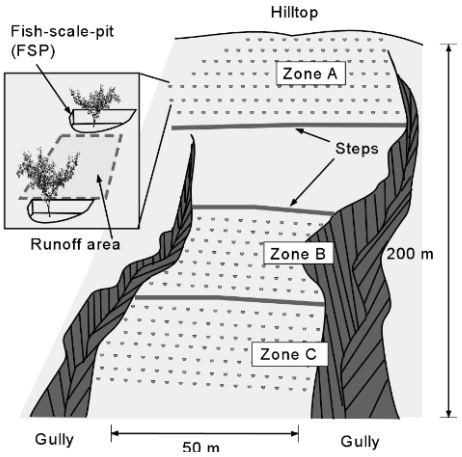


Fig.2 Schematic diagram of the field site

Dielectric sensors have been widely used for non-destructive determination of volumetric soil water content. Since the output of such sensors is affected by soil temperature and salinity, the calibration for the effect is indispensable for accurate determination of water content. The objectives of this study were (i) evaluation of the temperature effects on outputs of the commercial capacitance probes called ECH2O probes for various types of soils, and (ii) to include temperature in empirical calibration equations. I also briefly considered the theoretical background of temperature effects on the probe outputs based on the results from the experiments and the properties of the soils tested. To demonstrate the importance of temperature calibration, the derived calibration equations were applied to two field observations from arid lands.

Dr. Bouya Ahmed OULD AHMED (JSPS Postdoctoral Fellow)

My research is about investigation of sustainable drip irrigation scheduling using poor quality water under arid land environments. The major objective was to assess the impact of saline water drip irrigation management options and soil degradation, induced by salt accumulation in the soil profile.

Experiment was conducted in Arid Land Research Center and in Mauritania in collaboration with Institute of Sciences and Technology to examine the possibility to increase crop productivity by using ‘porous alpha’ as amendment (recycle martial from bottle glass).