1. Research Activities (Apr. 2009-Mar. 2010)

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, five associate professors and four assistant professors. The other division has one associate professor. The all division has one visiting professor and two associate professors from Japan and three visiting researchers from abroad. In addition, 11 project researchers are stationed at ALRC. Twelve office staff (six clerks and six associate clerks), five technical officers and a research support technician support the research and education.

Joint-Use Research, Education, Publication

During the fiscal year of 2009, 65 Joint-Use Researchers (Teachers from national and private universities) were attached to the Center. The number of students as of October 2009 is 32 (18 Ph.D. Students, 9 Master Students, 3 Undergraduate Students, 2 Research Students).

Seminars were often held by a large number of internal and external experts. The foreign visiting researchers 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 8, 2009 at Arid Land Research Center, Tottori University.

On September 14-15, 2009, Core University Program 'CAS-JSPS Core University Program Japan-China joint open seminar on combating desertification and development in inland China of year 2009' 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 (Grants-in-Aid for Scientific Research from the Japanese Ministry of Education, Science, Sports, and Culture)
(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 COE program for Dryland Science)

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 2009, 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 carried out the field survey on irrigation and agriculture at Dakhla Oasis in Arab Republic of Egypt and Sinmuu in .People's Republic of China. Also, we exchanged information of irrigation efficiency with irrigation engineers in People's Republic of China and Hashemite Kingdom of Jordan.

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), Assistant professor Aoda Tadao. (Faculty of Agriculture, Niigata University) and professor Kato Hiroshi (Department of Economics, Hitotsubashi 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:

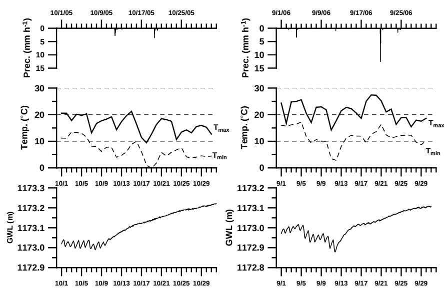
- Research on the land surface processes in the dust source regions – With the purpose of reflecting to the policy for controlling the dust emission
  Japan Society of the Promotion of Science Grants-in-Aid for Scientific Research (B), 2008-2011 (Project Leader: R. Kimura)
- Dynamics of drought memories
  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)
- Verification of restraint technology for dust storm in arid region of northeast China, and diffusion to the hazardous area
  Japan Society of the Promotion of Science Grants-in-Aid for Scientific Research (B), 2009-2014 (Project Leader: N. Matsuoka)

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 to monitor the dust emission, (3) Zhangye of China to install the dust monitoring system under the cooperation 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 Hydrology Subdivision carries out research on the monitoring and modeling of hydrological phenomena in the dry environments. In the fiscal year research activities covered China, Egypt and Sudan. In China groundwater and soil water movement in a small watershed (dam farmland) of the Loess Plateau was observed and analyzed as activities on project of the Global COE and Core University. The result showed that water uptake by plants was pronounced except the evaporation. As limited water resources in the arid environment, groundwater has an important role on plants growing. On behalf of the international cooperation project of the EU, water movement through the vadose zone in Sinai, Egypt was analyzed. As a new project, study on relationship between mesquite and groundwater in Sudan has started in this fiscal year.



Termination of plants water uptake in autumn (in China).
Diurnal fluctuation of groundwater due to the water uptake terminated when temperature became lower.

Mesquite in Sudan.
Leaves of mesquite are green even in the dry season, as mesquite has powerful ability of water uptake from deep groundwater.

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:

- Research on the photosynthesis and water use efficiency of *Jatropha curcas*
- Research on the effects of simulated nitrogen deposition on grassland in the northern Loess Plateau region of China

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 National Institute of Forestry, Agricultural and Animal Research (INIFAP) of Mexico to carry joint research and field survey in Mexico City and Chiapas. I participated in the meeting of Committee on Science and Technology (CST) of the

United Nations Convention to Combat Desertification (UNCCD) held in Buenos Aires, Argentina from September 20 to 27, 2009.

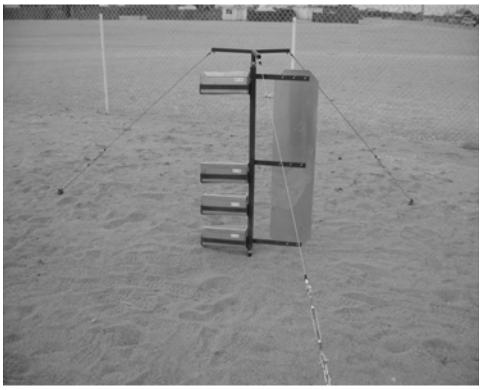
Field experiment on effects of simulated nitrogen deposition on grassland in the northern Loess Plateau region of China. Nitrogen promotes plant growth shown in dark green.

Assoc. Prof. Ping An (Plant Ecophysiology)

Physiological responses of plants to salt and drought stresses (child-care leave)

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 build and test plant growth and production models. The current research topics are:



A dust trap set up at Hanbogd meteorological station in Mongolia

- Plant response to drought
- Model development of plant growth in drylands
- Risk assessment of plant production in drylands
- Framework of a drought early warning system.

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

- Observation of dust outbreaks in the Steppes of Mongolia
- Development of an integrated drought early warning system for dry grassland in South Africa
- Investigation of the effect of natural plant strengthening agents on wheat.

Assist. Prof. Wataru Tsuji (Crop Eco-physiology)

The Crop Eco-physiology Subdivision has conducted 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 response to environmental stress and its resistance mechanism in crops, to develop cultivation technology for enhancement of water use efficiency and mitigation of drought stress in dryland agriculture with combining the basic research in Japan using the Center’s facilities and applied research at real fields in drylands. In the fiscal year, I continued the field experiments in ICRISAT (International Crops Research Institute for the Semi-Arid Tropics) to investigate the optimal degree and timing of defoliation for enhancement of grain yield and water use efficiency under drought stress in sorghum and wheat.

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 in India for field experiments, and to Institute of Soil and Water Conservation (ISWC) of the Chinese Academy of Science (CAS) for participation and presentation in "Japan-China Joint Open Seminar on Combating Desertification and Development in Inland China".

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 central Asia. 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.

In the fiscal year, we surveyed environmental factors such as vegetation in Mongolian Gobi, and analyzed relationships between movements of wild ungulates and environmental factors. We also studied 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. We started a new research project on migration of endangered saiga antelope in Kazakhstan.

Overseas research activities during the fiscal year include field researches in Mongolia, Kazakhstan, and South Africa, and attending conferences in China, Argentina, and Taiwan.

Saiga antelope in Ustyurt Plateau, Kazakhstan

Assist. Prof. Tomoe Inoue (Crop Physiology)

Research has been conducted to characterize the morph-physiological mechanisms mediating drought and heat resistance in wheat in collaboration with scientists at the International Center for Agricultural Research in the Dry Areas (ICARDA, Syria). In the fiscal 2009, I studied on the physiological trait related to the higher post-anthesis assimilation in synthetic hexaploid wheat derivatives under severe drought condition. Also pot experiment was conducted at the growth chambers to evaluate the effect of air/soil high temperature stress on photosynthesis in wheat genotypes.

Striga hermonthica is a root parasitic weed and one of the serious constrains on crop production in the dry areas of Africa. To clarify the mechanisms on water and solutes uptake of *Striga* from its host plants, I have conducted joint research at the Sudan University of Science and Technology. In the fiscal 2009, the stomatal response of *Striga* and its host sorghum were studied under different soil water regimes and foliar application of abscisic acid.

Overseas activities during the fiscal 2009 were included visit to ICARDA to conduct joint research on drought and heat resistance in wheat. And I visited the Sudan University of Science and Technology to conduct the experiment on *Striga*.

3) Division of Afforestation and Land Conservation

Prof. Mitsuhiro Inoue (Land Conservation)

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 water-saving irrigation for sustainable production in The International Conference on Water Conservation in Arid Regions in Jeddah (Saudi Arabia) in Oct. 2009 and The ASA-CSSA-SSSA 2009 International Annual Meetings in Pittsburgh (Pennsylvania, USA) in Nov. 2009, and published the result in the Journal of Food, Agriculture and Environment. I belong to agricultural production group in the Global Center of Excellence (GCOE) program, and have proposed the suitable wheat cultivation and management under saline water irrigation with arid condition, and published the result in the Agricultural Water Management. We obtained the outside funds of the Grant-in-Aid for Scientific Research (Management of Nutrients and Sediment losses from Tropical Acid Soil Environment), the 2009 Digital Manufacturing Development and Demonstration Research Project supported by the Japan Small Business Corporation (Water-saving Vegetable Cultivation in Arid Regions) and some others. My group has two doctoral students (international), six master's students, and one undergraduate student under my direct supervisor, fifteen 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. They got MS-program certificate by research presentation in China. Mr. Zhang took Doctor degree of Agriculture within 3 years titled 'Study on evaluation of mulching effect and establishment of irrigation threshold foe water saving production' in Sep. 2009.

Overseas research activities during the fiscal year included visits to China (Apr., May, Dec. 2009), Mauritania and Qatar (Jun., Sep. 2009), and Egypt (Dec. 2009, Mar. 2010). 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.

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

As the overseas activities of the fiscal year, the research on ecosystem restoration was carried out in the Loess Plateau of China in September 2009 and January 2010. In August 2010, the collaborative research on Invasive *Tamarix* forest was carried out along Virgin and Colorado Rivers with Desert Research Institute (DRI). Collaborative research on Halophyte in Western Inner Mongolia was also carried out with Inner Mongolia University in March 2010.


Invasive Tamarix along Virgin river of Nevada,US

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.

Research grants in the fiscal year include:

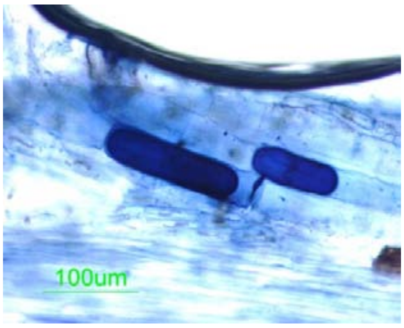
Elucidation of osmo-regulation mechanisms and improvement of drought and salt tolerance of plants for revegetation in arid areas.

Japan Society of the Promotion of Science Grants-in-Aid for Scientific Research (B), 2009-2012 (Project Leader: N.Yamanaka)

Assist. Prof. Takeshi Taniguchi (Microbial Ecology)

The Microbial Ecology Subdivision studies on the ecology and physiology of symbiotic microorganisms (mycorrhizal fungi, endophytic fungi and endophytic bacteria) of plants living in dry lands.

Aims of the studies are to reveal the ecophysiological features of symbiotic microorganisms and to search for the useful microorganisms for ecosystem restoration. The main research topics in the fiscal year were as follows:



Arbuscular mycorrhizal fungi in Tamarisk root

- Distribution and community structure of microorganisms (mycorrhizal fungi, endophytic fungi and endophytic bacteria) in Tamarisk (*Tamarix ramosissima*) roots along the gradient of salt in Southwestern America.
- Vertical distribution of microorganisms (mycorrhizal fungi, endophytic fungi and endophytic bacteria) in Tamarisk (*Tamarix ramosissima*) roots in Southwestern America.

Overseas research activities during the fiscal year include the collaborative studies with Desert Research Institute (DRI) in Southwestern America and the Institute of Soil and Water Conservation (ISWC) of the Chinese Academy of Science (CAS) in Losses Plateau in China.

4) Division of Socioeconomics

Assoc. Prof. Takayuki Ando (Arid land development)

The Socioeconomic Division aims to construct a social system to promote the sustainability of environment and society in arid land. As part of this effort, research and surveys on the sustainable rural development system in arid lad using biofuel plants have been conducting. *Jatropha curcas* L. has been focused principally as a biofuel feedstock because this plant is drought-resistant 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.

The main activities in fiscal 2009 were:

(1) information collection and analysis of biofuel development policy of the Mexican Government and field survey on the actual situation of cultivation of *Jatropha curcas* in few states of Mexico where is located at the northern part of the center of origin of this feedstock.

(2) conclusion of the Specific Accord of Scientific and Technical Cooperation between Tottori University and the National Institute of Forestry, Agricultural and Animal Research (INIFAP) of the United Mexican States to establish Core Collection of *Jatropha curcas*, inviting the General Director of INIFAP to Tottori University in March 2010.

Jatropha and farmers

5) Division of Health and Medicine

Visiting Associate 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
- Assessment of nomadic health and vulnerability in Mongolia

Research grants in the fiscal year include:

Risk assessment of dust storm on animal husbandry in Mongolia

Japan Society of the Promotion of Science Grants-in-Aid for Scientific Research (B), 2009-2013
(Project Leader: M. Shinoda)

Overseas research activities during the fiscal year include visit 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.

(3) Foreign Researchers

Dr. Mohan Chandra SAXENA (Arid Land Ecophysiology)

September 2008 – October 2009
International Center for Agricultural Research in the Dry Areas, Syria
Title: Response of a fuel plant (*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 under controlled environmental conditions to develop some of this information:

(a) Experiment 1: Effect of boron concentration in irrigation water on the germination of seeds of *Jatropha curcas* provenances 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 *Jatropha curcas* seedlings to application of farm yard manure.
(e) Experiment 5: Response of *Jatropha curcas* seedlings to irrigation with saline water at different rates of application of farm yard manure.
(f) Experiment 6: Determination of leaf area of *Jatropha curcas* based on the measurement of some leaf parameters.
(g) Experiment 7: Response of *Pongamia pinnata* seedlings to irrigation with saline water and water with 6 mg boron per liter.

Titles of articles:

- Following paper was presented in the 9th International Dryland Development Conference held at Alexandria, Egypt, 7-9 November 2008 based on the work done on *Jatropha curcas* at the Center: “Dry areas provide good prospects for biofuel production”.
- The results of experiments listed above will be published in three papers to be submitted to the Journal of Plant and Soil and Agriculture Water Management and Journal of Agricultural Sciences.
- The Proceedings of the 9th International Dryland Development Conference held at Alexandria, Egypt,

7- 9 November 2008 are being edited and will be published in early 2010.

Result of research conducted:

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. The results of this study show 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. In the summer months when there is no rain, there is no alternative but to use this water to establish the seedlings. The objective of this experiment was to examine the effect of saline water irrigation on the growth and some physiological parameters of one and half months 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. Objective was also to see if the adverse effect if any of the saline irrigation could be reduced by leaching with water simulating the rainfall events common in the monsoon season in the semiarid and arid areas.

The experiment was conducted in glass house (biohazard room), with natural light conditions and a temperature regime of around 25^{o} C and a relative humidity of about 30%, using 1/5000 a Wagner pots with 5 kg of dune sand with free drainage. Seedlings 39 days old with at least one fully opened primary leaf were transplanted, with roots intact in the sand. Plants were fertilized with granular compound fertilizer (5 %N+ 10%P+ 7%K) at the rate of 5.5 g per pot. The pots were irrigated with tap water till free drainage occurred. After letting the pots drain overnight their weight at field capacity was determined which was used as the base line for the irrigation in the future. The water lost per pot by evapotranspiration was determined by weighing the pots frequently. About 70% of the field capacity (FC) water content was allowed to deplete before irrigation was given to bring the moisture content back to FC. The treatments included two provenances of Jatropha (Tanzanian, T and Kenyan, K) and irrigation with water of three salinity levels created by dissolving NaCl in tap water (tap water - S0, 100mM - S1 and 200mM NaC l-S2). The EC values were 0.09, 10.5, and 19.6dSm^{-1}, respectively. Thus there were six treatment combinations (TS0, TS1, TS2, KS0, KS1, and KS2), replicated three times. The differential treatments were started on 2 March 2009 when the seedlings were nearly 54 days old. The plants under S1 and S2 treatments showed drooping of leaves immediately after application of saline water, particularly at the highest concentration (EC=19.6 dSm^{-1}), for the first time, but showed recovery later. No such effect was observed in case of the treatment with lower level of salinity (EC=10.5dSm^{-1}). However, after the further cycles of irrigation they stated showing the drying of lower leaves, starting from the margins, and by 23 March (21 days after the start of the treatment) the symptoms were rather severe. The amount of salt water received by 23 March was 13.85, 27.62, 13.65 and 24.95g NaCl per pot, respectively in TS1, TS2, KS1 and KS2. Because of the development of toxicity, saline irrigation was stopped after 23 March and all the pots were irrigated with tap water from then on. However the toxicity symptoms increased because of the salts present in the pots and two of the three Tanzanian plants showed complete drying of leaves by 31 March under TS2. Thus, the Tanzanian provenance appeared to be more sensitive than the Kenyan one to salinity (Photo 1).

Photo 1. Effect of saline irrigation on plant growth on 16 April, Tanzania - 3 left pots , Kenya - 3 right pots; sequence: S0, S1, and S2.

Because of the growing severity of symptoms of salinity toxicity, on 15 April (43 days after the start of saline irrigation) the pots were brought to FC and then leached with 1000 ml of tap water in two splits, simulating two rainfall events of 25 mm each. The EC of the leachate was determined (Fig. 2). As expected, it increased as the salinity of irrigation water increased, and was higher in the first leachate than in the second. As the EC of the second leachate was also high, there is the likelihood that the salts were not completely removed by the 50 mm simulated rainfall. All the fully opened green leaves were harvested, photographed and their dry weight determined. The plants showed fast re-growth of the undifferentiated leaves in the top, with re-growth being slower under S2 and S1. On 27 May, fully opened leaves were again harvested and plants allowed to re-grow. On 25 June (114 days after the start of saline irrigation), all the plants were finally harvested, and dry weight of leaves, stem and roots determined.

The number of green leaves per plant at the first harvest (15 April) was drastically reduced by salinity. After the stress was reduced by leaching, the leaf number during the two re-growths increased with time under all the treatments, the recovery from salinity stress being particularly high in the Kenyan provenance. The dry weight of green leaves measured at the first and second harvest dates from the same plant reflected the adverse effect of high level of salinity in the irrigation water and better tolerance of Kenyan provenance. In the third harvest, there was excellent recovery from stress under all treatments, particularly in the Kenyan provenance. The rate of photosynthesis, transpiration rate and stomatal conductance were severely decreased by salinity even just after two cycles of saline water irrigation. Plant height, stem diameter and the dry weight of stem, shoot (stem +leaves), root and whole plant at final harvest on 25 June all decreased with saline irrigation and decrease was more at S2 than S1. The stem dry weight was reduced by 53% and 90% under S1 and S2, respectively in Tanzanian plants and by 54% and 76% in Kenyan plants as compared to S0. The corresponding reductions in total shoot weight were 39% and 87% for Tanzanian plants and 40% and 59% in Kenyan plants.

The above results have shown that irrigation of seedlings with saline water up to 100mM NaCl /L concentration for a limited period of time can be tolerated by *Jatropha curcas* but irrigation with saline water containing 200mM NaCl/L would severely restrict plant growth, and may even cause death of the seedlings. Removing the salinity load by leaching would permit the seedlings to recuperate from the stress and can eventually grow almost at same rate as the plants that received irrigation with non saline water. Thus, under dry areas the seedlings of *Jatropha curcas* can be protected by irrigating them with saline water before the monsoon rains would set in. The results also show that provenances of *Jatropha curcas* differ in their tolerance to salinity and of the two provenances tested in this study, Kenyan provenance showed consistently better tolerance than Tanzanian one, even to the highest level of NaCl concentration (200mM/L) tested. The study has also permitted identification of the symptoms of salt toxicity pattern of their development, which would be of use in the management of Jatropha plantations.

In an ancillary experiment, five plants of Kenyan provenance were irrigated with ten-time diluted sea water (one part sea water mixed with 9 parts of tap water on volume basis, EC= 5.56 dSm^{-1}) to explore the possibility of using diluted sea water for irrigation to establish *Jatropha curcas.* The treatment was started on 18 March 2009 when plants were nearly 45 days old. Two treatments were tested: T1-irrigating continuously with diluted sea water; T2- every second irrigation with tap water (EC 0.094 dSm^{-1}). The differential saline irrigation treatments were terminated on 21 April, when the plants started showing the symptoms of salt toxicity, and all the pots started receiving irrigation with tap water. On 22 May the pots were leached out to reduce the salt load. On 26 May, all the fully open green leaves were harvested and plants allowed making re-growth. One month after leaching final harvest was made and dry weight determined. Green leaf number became lower in T1 by 22 May, showing more stress under T1 than T2, but the differences disappeared at the end of the experiment. There was no difference in the plant height between the two treatments but the stem diameter was reduced under T1, particularly in the early period after the start of differential treatment, showing the sensitivity of stem diameter to salinity stress. Photosynthesis and other gaseous parameters were measured on the topmost fully opened leaves on 9 April showed the superiority of T2 over T1, reflecting that T1 caused more stress. There was no effect of the treatments on the dry matter yield in stem, shoot. In conclusion, 1/10 diluted sea water having an EC of 0.556dS/m can be used for irrigating Jatropha seedlings during the dry pre-rainy season period with out any major adverse growth effect on the plant, if the stress is relieved by leaching in 2 months after the start of saline irrigation. If there is a possibility for the use of fresh water alternating with diluted sea water, the duration for irrigation with diluted sea water can increase. Dropping of leaves and reduction in the stem girth are good indications of the salinity stress to Jatropha plant.

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

The quality of irrigation water in many dry areas is also poor. At places it contains high levels of boron (B). In the summer months when there is no rain, there is no alternative but to use this water to establish the seedlings. The objective of this experiment was to examine the effect of irrigation with water having four different concentrations of B on the growth and some physiological parameters of nearly two months old seedlings of Tanzanian *Jatropha curcas* and whether the adverse effect of B if any could be reduced by leaching with fresh water simulating the rainfall events common in the monsoon season in the semiarid and arid areas. The experiment was conducted in the biohazard room, using 1/5000 a Wagner pots with 5 kg of dune sand with free drainage. The treatments included four levels of boron in irrigation water (0, 2, 4, and 6 mg B per liter, designated as B-0, B-2, B-4, and B-6, respectively) prepared in tap water with boric acid. The differential treatments started on 2 March. There were three replications. The plants received on an average 5586± 257ml of water (11.17 mg B) under B-2, 5797± 128ml of water (23.19 mg B) under B-4, and 5481± 126ml water (32.89 mg B) under B-6 treatment by 15 April.

Unlike with salinity treatments, the plants showed no immediate effect of irrigation with B concentration as high as 6 mg/L. Till 2April (31 days after the start of B treatment) the plants showed no symptoms of any damage. On 9th April, foliar symptoms (drying of the margins of lower leaves, particularly where the main veins terminated and general paling of leaves) appeared under B-4 and B-6. By 15 April, the severity increased. Hence, the differential treatment was terminated by irrigating all the plants with tap water and leaching the soil with 1000 ml of tap water. The leaves were harvested on 16 April (Photo 2).

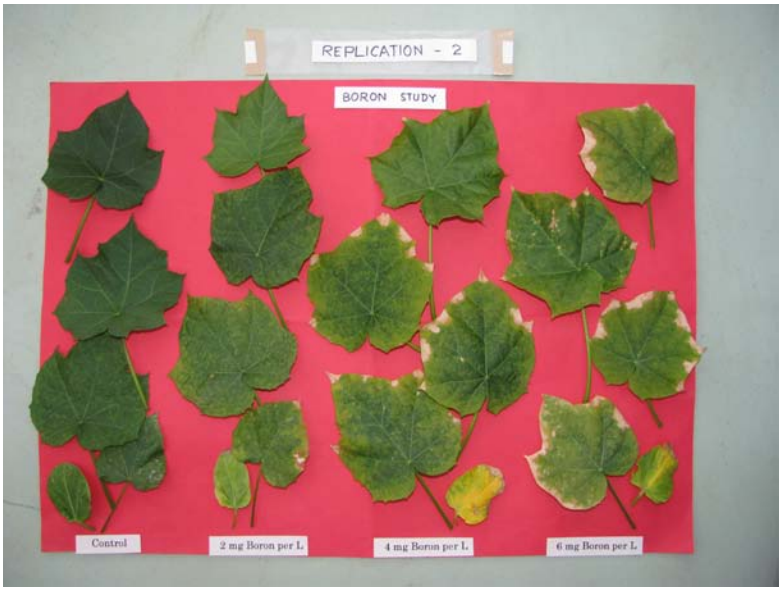


Photo 2. The lower most five leaves from plants receiving B-0, B-2, B-4 and B-6 treatments (from left to right), showing symptoms of B toxicity on 16 April.

Plant growth (number of green leaves, stem diameter, and plant height), gaseous exchange rates and the consumptive use of water was monitored throughout the experiment and the dry weight of green leaves was determined three times: (a) the first time, at the end of differential treatment application on 16 April 2009, when all the fully expanded leaves were harvested and plant allowed to develop new leaves from the apex; (b) the second time, on 26 May 2009 when all the fully expanded new leaves were harvested to assess the recovery from B-stress, and plant further allowed to develop new leaves; and (c) the third time, on 23 June 2009 when the experiment was terminated by harvesting the whole plant for determination of dry matter in different parts.

The number of green leaves at different period of time remained unaffected by the B-treatment; although there was a tendency for the number to become slightly lower under B-4 and B-6 treatments on 16 April and this trend persisted in the first re-growth till 26 May. In the second re-growth, the differences disappeared by the time the final harvest was made on 23 June. The dry weight of green leaves (Fig.3) was not much affected by the treatment on the first harvest date (16 April), but there was a significant decrease in the dry weight re-grown leaves under B-6 at the second harvest date, reflecting the residual effect of the treatment. At the final harvest date (23 June), the treatment difference disappeared, revealing the recovery of the plants from the stress experienced in the previous period. Total leaf productivity showed only marginal decrease under B-6 treatment, and it was not significant. The gaseous exchange in the uppermost fully expanded leaf was not much affected by B-treatments, showing that in spite of phyotoxicity on the older leaves, the newly developed fully expanded leaves continued to photosynthesize normally even at high B-content.

Stem and shoot (stem+leaves) dry weight and gross shoot dry weight (sum of the leaf dry weight harvest at all the three stages and the stem dry weight), reflecting total productivity of the plants, showed that there was no effect of irrigation with B-rich water containing as high a concentration as 4mg B/L, but with 6mg B/L, there was some adverse effect, which did not reach the level of significance. At the end of the experiment, i.e. 113 days after the start of the treatment and 69 days after the pots were leached, the plants under all the treatments showed nearly identical growth showing excellent recovery.

Results suggest good tolerance of boron levels up to 6mg per liter in the irrigation water by the young plants of Tanzanian *Jatropha curcas* provenance for a period of nearly 45 days at which time the plants started showing symptoms of phytotoxicity on the lower leaves although the physiological functions of upper fully opened leaves remained unaffected. Flushing the soil of accumulated B by leaching with 1000 ml of tap water (equivalent of 50 mm of rainfall) allowed the plants to completely recover from the B-toxicity.

Experiment 4: Response of *Jatropha curcas* seedlings to application of farm yard manure

One of the reasons as to why *Jatopha curcas* is considered as a sustainable source of biofuel is its ability to grow on marginal lands. In the arid areas large tracts covered with dune sand are available for its cultivation if the seedlings could be established with irrigation. However, these sands are poor in organic matter content, and hence have not only poor fertility but also poor water holding capacity. Application of organic manures can therefore improve the early establishment of JC plants under irrigation on dune sands and improve the water use efficiency. The objective of this experiment was to examine the effect of application farm yard manure (FYM) on the growth and some physiological parameters as well as water use of seedlings of Tanzanian *Jatropha curcas*. The experiment was conducted using 1/5000 a Wagner pots with 4 kg of dune sand with free drainage. The treatments were no manure (M0), 40g manure per pot (M1), and 80g manure per pot (M2), corresponding to 0, 20 and 40 Mg FYM per ha, respectively. The manure used was ‘Hai-Yu-Uki’, containing a well decomposed mixture of cattle waste, sawdust and bark, produced by Gokyu Bokujo Hakko Taihi Center, Okayama prefecture, Japan. Its composition was: 0.8% N, 1.13% P_2O_5, and 1.09% K_2O and it had a C: N ratio of 17.8:1. To avoid the fertility difference amongst the treatments, all pots were given inorganic liquid fertilizer (HYPNeX 6-10-5, 1ml/L) frequently, starting right at the time of transplanting of seedlings on 23 April. The irrigation was given based on the water loss determined by the regular weighing of pots. When 60 to 80% of the water at FC was exhausted, the pots were irrigated with tap water to bring the moisture content back to FC.

Improvement in plant growth because of manuring started becoming evident in May itself and growth differences became more conspicuous with time. Photo 3 shows that growth differences on 30 July (98 DAT) when the plants in all the three replications were harvested for dry weight determination. The M1 and M2 plants were taller to M0 plants at all the stages, and the difference tended to increase in time. However, there was little difference between the M1 and M2 plants. Number of green leaves showed the same trend.

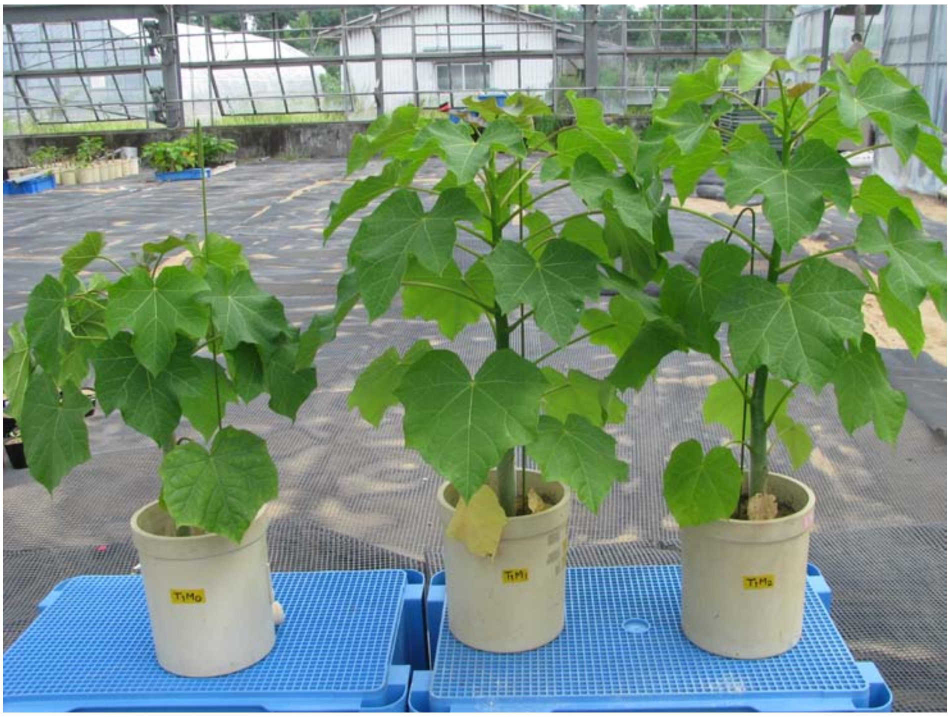


Photo 3. Effect of manuring on the growth of Tanzanian Jatropha curcas on 30 July (98 days after transplanting). From left to right – M0, M1, and M2.

The cumulative number of yellow/dried leaves was higher under M0 than under M1 and M2, and the increase occurred earlier in M0, while in M1 and M2 this occurred late (after 26 July). The rate of photosynthesis was slightly higher under M1 treatment than M0, while it was nearly the same under M0 and M2. The stomatal conductance transpiration rate and internal carbon dioxide concentration tended to decrease with M2 as compared to M1 and M0, although the differences were not significant. The stem diameter initially tended to decrease as the level of manuring increased, but at the later two dates it increased with manuring over M0. Shoot (stem + green leaves + dry leaves) dry weight on 30 July was highest under M1 (128%) followed by M2 (122%) and the lowest under M0 (100%). Root dry weight also increased with manuring.

The general observation of the plants as they grew and the measurement of various parameters indicated that there was an over all positive effect of manure application, but there was no major advantage of having higher rate of manure application over the lower one. As the supply of the major inorganic nutrients (N,P and K) was ensured be sufficient under all the treatments by repeated application of liquid fertilizer, the effect of manure should be ascribed to factors other than the N,P, and K carried by the manure. It is to be noted that, all the manure treated plants initially showed some toxicity, expressed in the form of puckering of upper young unfolded leaves, and reduction in stem thickness. There was also suppression of stem diameter initially because of manure application. The rate of photosynthesis was not much affected by the treatments although there was a clear superiority of M1 over M0 and M2, and there was tendency for the stomatal conductance and transpiration to decrease with M2 in comparison to M1 and M0. On the other hand, the manure application promoted plant height and leaf number and leaf dry weight fairly early on, and the M2 level being slightly superior to M1. It is therefore suggested the manure used in this experiment had two contrasting effects, one with a negative consequence for the plants and the other with a positive consequence. The positive effect was perhaps associated with improved soil physical condition through increased organic matter that should theoretically increase with increase in the rate of application.

The second positive effect was possibly associated with some kind of hormonal effect, as reflected in increased plant height, leaf number (including increased number of axillary leaves) and leaf dry weight, slower yellowing of cotyledonary leaves, etc., with increasing rate of manure application. The negative effect was perhaps associated with some kind of stress caused by some constituent present in the manure, as was reflected in the development of symptoms of puckering on the younger leaves, lesser stem diameter early on and reduced rate of gaseous exchange in the leaves. These effects should be expected to increase with increase in the rate of application. The sum total of these two contrasting effects is that in terms of overall growth and dry matter productivity, the M1 treatment surpassed M2, and both these two treatments surpassed the M0 treatment. It should be stated that these are only speculations, and there is a need that some of these possibilities are further examined through detailed experimentation.

The study has demonstrated that there is definite advantage of applying farm yard manure to *Jatroph curcas* seedlings when they are being established on dune sands. The rate of application of manure should however not exceed 20 Mg/ha.

Experiment 5: Response of Kenyan *Jatropha curcas* seedlings to irrigation with saline water at different rates of application of farm yard manure

The soils in many dry areas are poor in organic matter content, and the water available for irrigation during the dry season is generally brackish. It is therefore important to know the extent to which the application of organic manures can improve the early establishment of JC plants under irrigation with saline water on dune sands. In Experiment 2 above, it was already observed that Kenyan provenance was more tolerant to irrigation with saline water, but application of water with 100 or 200mM NaCl concentration resulted in development of phytotoxicity within a month. Hence it was proposed to test a lower concentration of NaCl (50mM) so that the duration of period in which saline water irrigation is given could be extended. The objective of this pot culture experiment was therefore to examine the effect of application of farm yard manure (FYM) on the growth and some physiological parameters as well as water use of seedlings of Kenyan *Jatropha curcas* irrigated with tap water and water with 50mM NaCl concentration. The treatments were all combinations of two levels of salinity in the irrigation water (S0 - tap water, EC 14.65mS/m; S1 - saline water containing 50mM NaCl, EC 0.649 S/m) and three levels of FYM - no manure (M0), 40g manure per pot (M1), and 80g manure per pot (M2), corresponding to 0, 20 and 40 Mg FYM per ha, respectively. Because of limited number of seeds, only four replications were used, three of which were retained for the whole period of the experiment and one was harvested before the start of salinity treatments.

The methods used in raising seedlings and irrigation were the same as in Experiment 4. Growth differences because of manuring started becoming evident fairly early on. From 4 July (78 days after emergence, DAE,), the saline irrigation treatment was started, and the pots were irrigated with either tap water or saline water as per the treatment. The total amount of saline water (50mM NaCl) given under S1M0, S1M1 and S1M2 treatment combinations was 4020, 4835, and 5142 ml, respectively, adding on an average 11.746, 14.128 and 15.025g NaCl per pot in the respective treatments. On 30 August (135 DAE, and 57 DASIT) the experiment was terminated by harvesting all the fully opened green leaves, whose moisture content and dry weight were determined. The pots were then leached with 1500 ml water and the EC of leachate determined. As expected, the EC in S1 pots was almost 10 times of that in S0 pots, and it increased as the rate of manuring increased, by about 17% under M1 and nearly 37% under M2. The plants were then left for re-growth and irrigated with nutrient solution and tap water every week. On 15 September, the re-growth was visually assessed.

Improvement in plant growth because of manuring became evident in May itself and growth differences became more conspicuous with time. The M1 and M2 plants were taller to Mo, and the M2 plants had several axillary leaves. On 25 July (21 DASIT), S1 plants with no manure (S1M0) started showing puckering of the young leaves in the crown, while no such symptoms were there under S1M1 and S1M2 treatments. The fully opened old leaves remained fully turgid under S1 treatment, while under S0 treatment occasional signs of moisture deficit were noticed on bright days, particularly with M2 and M1, before irrigation. It appeared that S1 plants were able to maintain their water balance better than S0 plants between the two irrigation cycles. However, by 16 August, the crown leaves started showing more severe bronzing and suppression of expansion because of saline irrigation, irrespective of the level of manuring. On 15 September, the plants showed reasonable re-growth, the plants under S1 treatment showing better growth than under S0, and S1M1 plants showed good axillary leaf growth.

The CWU from 30 June to the end of the experiment on 30 August was reduced by nearly 50% because of saline irrigation, while manuring increased it by about 25%. Plant height increased with time in all the treatments. Manure application accelerated the plant height from the very beginning (30 June) and the effect became more conspicuous as the plant grew (Photo 4).

Photo 4. Plant growth on 30 August as affected by treatment combinations. From left to right: S1M0, S0M0; S1M1, S0M1; S1M2, S0M2.

The salinity treatment tended to reduce the growth from 15 July onwards, and it reduced the final height by 3% under M0, 12% under M1 and 16% under M2. Thus, manuring application did not ameliorate the adverse effect of saline irrigation. Manuring resulted in higher leaf number at all the stages, and the difference increased with time. On 30 August (the last stage), the salinity treatment reduced the green leaf number by 10% under M0, 13% under M1 and 35% under M2. Thus, salinity effect was accentuated by increasing rate of manure application. Photosynthetic rate, stomatal conductance and transpiration rates, measured on 18 August, were drastically reduced by saline irrigation

As the plants were not harvested at the end of the main experiment to allow a follow up on the re-growth after the salinity stress was removed, only leaves were harvested. Leaf weight was drastically reduced by saline irrigation. The reduction in the weight of green leaves was 44.2%, 51.5% and 67.7% under M0, M1 and M2, respectively. The reduction in the total leaf weight was of lesser magnitude, the respective values being 42.8%, 45% and 42%. It is clear therefore that manuring did not ameliorate the adverse affect of salinity on the leaf weight.

The general observation of the plants as they grew and the measurement of various parameters indicated that there was an over all positive effect of manure application, but there was only small improvement in the growth with the higher rate of manure application over the lower one. The saline irrigation suppressed the growth, and manuring was not able to ameliorate this growth suppression. On the contrary, in some traits, manuring accentuated the adverse effect of saline irrigation treatment. It is, therefore, suggested that, the manure in this experiment, like in Experiment 4, had two contrasting effects, one with a negative consequence for the plants and the other with a positive consequence. The positive effect was perhaps associated with improved soil physical condition through increased organic matter that should theoretically increase with increase in the rate of application. The second positive effect was possibly associated with some kind of hormonal material present in the manure, as reflected in increased plant height, leaf number (including increased number of axillary leaves) and leaf dry weight, slower yellowing of cotyledonary leaves, etc., with increasing rate of manure application. The negative effect was perhaps associated with some kind of stress caused by some constituent present in the manure, as was reflected in the development of symptoms of puckering on the younger leaves, lesser stem diameter early on, and the reduced rate of gaseous exchange in the leaves. The examination of EC of the leachate collected at the end of the experiment indicated that manure application increased the EC. Thus, part of the negative effect could be through this accentuation of the EC. The sum total of these two contrasting effects is that in terms of overall growth and dry matter productivity, the M2 treatment was only slightly superior to M1, and both these treatments greatly surpassed the M0 treatment.

The study has demonstrated that Kenyan *Jatroph curcas* seedlings can withstand irrigation with water containing 50mM NaCl for nearly two months without showing any major phytotoxicity. Once this salinity is removed by simulated rainfall, the plants are able to start re-growth that is even better than that of plants grown with tap water. The study has also shown that application of FYM at 20 Mg/ha or more is advantageous for rapid establishment of seedlings on dune sand. However, it has no major ameliorating effect on the growth suppression by saline irrigation. It appears that any possible ameliorative effect of FYM was masked by the effect of some component (s) in the FYM that had adverse effect on plant. It would be interesting to examine the composition of farm yard manure and also to compare it with other sources of organic matter to further test the hypothesis that addition of organic matter in dune sand would ameliorate the growth suppressing effect of saline irrigation on *Jatropha* plants.

Experiment 6: Determination of leaf area of *Jatropha curcas* based on measurement of some leaf parameters.

Plant leaves have important role in gaseous exchange, photosynthesis and water relations of green plants. Determination of leaf area is therefore very common in studying plant response to different agroecological treatments. Leaf area meters are now available for precise determination of leaf area both for the intact as well as the detached leaves, but their access in developing countries is still very limited and their use is labor consuming in case of plants that have large number of leaves of varying sizes. Hence methods are needed to precisely predict the leaf area from simple measurements of some key attributes of intact leaves. This study attempted to identify such a simple attribute based on the morphology of leaves of *Jatropha curcas* plants and develop its functional relationship with the leaf area.

The leaves of *Jatropha curcas*, irrespective of their location and size, show a remarkable similarity in the venation. They have a central main vein, running from the point of attachment of leaf lamina to the petiole to the apex of the leaf. There are two lateral main veins, one on the left and the other on the right side of the central vein. Then there are two nearly horizontal veins, one on the left and the other on the right side of the central vein. All these veins converge to the point of attachment of lamina to the petiole (Photo 5).

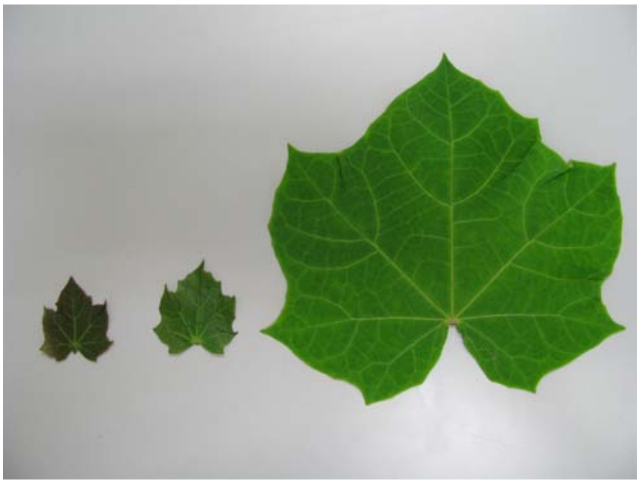


Photo 5. Leaves of *Jatropha curcas* showing the main veins: central vein, left lateral, right lateral and two horizontal veins.

We investigated the relationship between the lengths (x) of each of these veins with the area of the leaf lamina (y). We also investigated the relationship between the dry weight of lamina (x) and its area (y). All the 29 leave from one six-month old seedling and 22 leaves from another similar seedling of *Jatropha curcas* accession from Kenya were harvested and the length of their veins was measured. Then the area of each leaf lamina was measured using a leaf area meter (AAC-410 Automatic Area Meter, Hayashi Dekko Co., Ltd., Japan). The leaves were then dried at 80^{o}C and their dry weight determined.

The dependence of laminar area on each of the studied leaf parameters was investigated using a linear and a power function. Table 1 presents the summary of the results. Each of the vein length parameters showed high correlation with the leaf area, but the highest correlation of leaf area was found with the product of the length of central vein with the combined length of the two horizontal veins using both linear and power models, the latter showing a bit better fit than the former. The relationship of the leaf area with the combined length of the two horizontal veins was the next best. Dry weight of leaf lamina also showed very high correlation with the area of the lamina, but the fit was better with linear rather than the power function.

Table 1. Area of leaf lamina (cm^2) of *Jatropha curcas* as a function of various leaf parameters (length of central vein, left lateral vein, right lateral vein, and horizontal veins, product of central vein and horizontal vein lengths, and leaf lamina dry weight).

Parameters	Linear function		Power function	
	Model	R2	Model	R2
Length of central vein (CV), cm	y = 15.578 x - 48.908	0.8819	$y = 0.4813\ x^{2.3296}$	0.9637
Length of horizontal veins (HVs), cm	y = 12.475 x - 47.347	0.9168	$y = 0.3551\ x^{2.2539}$	0.9683
Length of left vein (LV), cm*	y = 17.307 x – 33.381	0.8340	$y = 0.9388\ x^{2.2208}$	0.9743
Length of right vein (RV), cm*	y = 17.343 x – 34.865	0.8644	$y = 1.0693\ x^{2.2791}$	0.9846
Product of CV & HVs, cm^2	y = 0.8167 x + 1.9482	0.9487	$y = 0.383\ x^{1.1625}$	0.9799

Leaf lamina dry weight, g	y = 227.04x	0.9220	$y = 237.04\ x^{1.0265}$	0.8958

* based on 29 leaves of one plant

It can be concluded from the study that the laminar area (y) in cm^2 of *Jatropha curcas* plants can be predicted based on the product (x) of the length (cm) of vertical vein with that of the sum of the two horizontal veins using the power function $y = 0.383\ x^{1.1625}$. If there is severe constraint of time/resources, the area (y) can also be reasonably predicted by measuring the combined length of two horizontal veins (x) using the power function $y = 0.3551\ x^{2.2539}$

Experiment 7: Studies on *Pongamia pinnata*

Pongamia pinnata (L.) Pierre is a fast-growing leguminous tree, native of Indian subcontinent and adapted to humid tropic and subtropical conditions. Its potential for high production of oil having properties suitable for making biodiesel and its ability to grow on drylands make it a promising plant for large-scale vegetable oil production. The water available for irrigation in many dry areas is generally of marginal quality—brackish or rich in B content. We investigated the ability of the pongamia seedlings to grow on dune sand when irrigated with saline water (containing 50 and 100mM NaCl in tap water of EC 0.098d Sm^{-1}) or tap water enriched in B (content 6 mg L^{-1} as H_3BO_3) using pot culture in the biohazard room with a temperature of around 25^oC, a RH of 35-40% and natural sun light.

Seedlings of an Indian accession were transplanted in 1/5000A Wagner pots containing a mixture of 60% dune sand+40% peat moss (vol. basis) and a compound (15-15-15) granular fertilizer to provide 50 kg of N, P and K each per ha. Plants were allowed to grow till 2nd March (106 DAT) when they were subjected to three levels of salinity in irrigation water (tap water, S0; 50mM NaCl, S1; and 100mM NaCl; respective EC values being 0.09, 4.9 and 9.8 dSm^{-1}), in three replications. Two plants were used to test the possibility of irrigation with B-rich irrigation water, which was started on 16th March.

Response to irrigation with saline water: After 3 weeks of saline water irrigation, there was a tendency for the S2 plants to start dropping lower leaves while no apparent symptoms of salt toxicity were visible. By mid April, the lower leaves of S2 and some S1 plants started showing toxicity on lower leaves. The symptoms became more conspicuous by 23 May (188 DAT) although the apical growth continued (Photo 6).

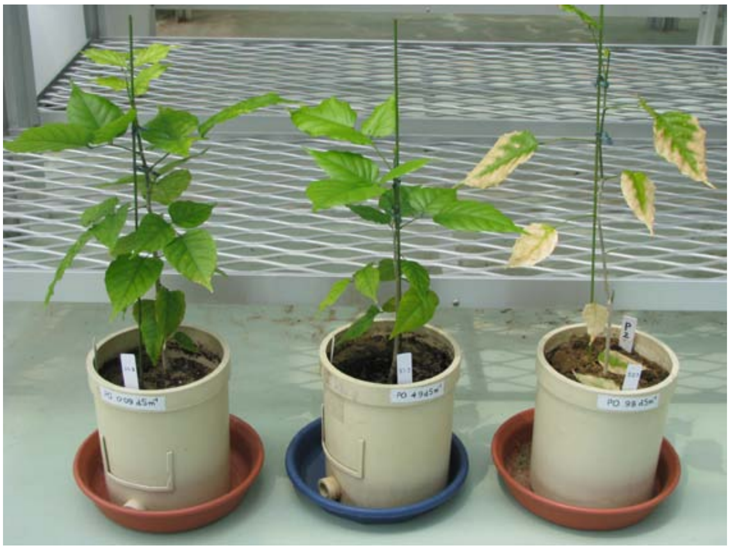


Photo 6. Effect of salinity on plant growth of *P. pinnata* on 23 May 2009

At this stage, irrigation with saline water was stopped and all pots were irrigated with tap water from then on. In 68 days of saline irrigation the S1 plants received 15.1g and S2 plants 29.2g NaCl per pot. . In spite of the stoppage of saline irrigation, the symptoms of salt toxicity became more conspicuous because of the presence of salt in the pot. Hence on 23 May (83 days after the start of and 30 days after the end of saline irrigation) all the pots were leached with 1000 ml of tap water in two splits. This would simulate a total of 50mm of rainfall. After leaching, the plants were regularly irrigated with tap water and given liquid fertilizer every 8-10 days.

Up to the first half of April (nearly 40 days after the start of salinity treatment) there were no significant differences in the growth parameters because of the treatments. The photosynthetic rate and other gaseous exchange parameters were measured on 9 April. Although the stomatal conductance, transpiration rate and intercellular CO_2 concentration were decreased as the level of salinity increased, there was no major effect on the rate of photosynthesis, which in general was low. The adverse effect of salinity on growth gradually started becoming conspicuous as the plant grew and by 23 May, the number of green leaves significantly decreased by salinity treatment. In fact the effect was more conspicuous on the number of leaflets. The stem girth measured on that day was also reduced. The plants started recovering after leaching and by 15th June the recovery was almost complete.

The results show that *Pongamia pinnata* saplings could withstand irrigation with saline water (100mM NaCl) for nearly two months and salinity for nearly three months. The plants were apparently able to restrict the symptoms of salt toxicity to lower leaves and maintain the growth of apical tissues.

Response to irrigation with water rich in Boron content: Irrigation with B-rich water was given from 16 March to 24 April providing about 20 mg B per pot. There was no apparent symptom of B toxicity up to 24 April (38 days after the start of treatment) although lower leaves senesced and dropped, while the apex continued differentiating in to new leaves thus allowing the number of green leaves to gradually increase. On 1 May (44 days after the start of treatment), the irrigation with B-rich water was stopped. Instead, the plants were irrigated with tap water. On 23 May (67 days after the start and 23 days after the stoppage of the treatment) the plants started showing symptoms of B toxicity by drying of the tips of lower leaves, and the laminar tissues where the veins ended, although the apex continued to grow. On 15th June (46 days after the stoppage of treatment), when toxicity on the lower leaves became very conspicuous, the pots were leached with 1500 ml of tap water. The plants continued to show increased toxicity on older leaves till 25 July because of the B accumulated in these leaves but also made new growth. The older leaves were detached and photographed (Photo 7). By early August, the plants showed complete recovery.

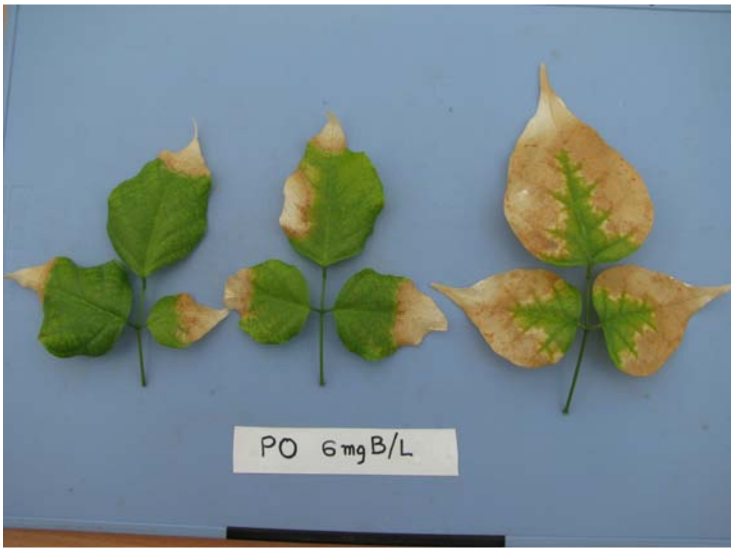


Photo 7. Symptoms of boron toxicity on the leaflets of *P. pinnata* on 25 July 2009

The results showed that saplings of *Pongamia pinnata* were able to withstand very high levels (6mg /L) of B in the irrigation water for nearly 38 days, and high B content in the rhizosphere for more than two months and recovered when the B stress was relieved by leaching the soil with tap water.

Dr. Waleed Hassan Mohamed ABOU EL HASSAN (Irrigation and Drainage)

April 2009 – March 2010

National Water Research Center, Water Management Research Institute, Egypt

Title: Development of water-saving irrigation techniques for upland rice cultivation

Summary of research activities:

Rapidly increasing food demand as well as limited water resources is threatening arid land countries. Agriculture consumes the largest amount of water, accounting for some 75~85% of total water use. Therefore, complete exploitation of the limited water resources is very important, especially by improving the irrigation systems. For example, in Egypt, high population growth is considered as one of the most serious development problems and it is predicted that the situation would further worsen because of limited water resources. Also, inadequate water supply has been identified as one of the central causes of poverty in developing countries, including Egypt, as it negatively affects their basic needs, health, food security and livelihoods. Therefore, following activities, experiments and studies have been conducted and evaluated in collaboration with other researchers during last year as follow:

Seminar Presentations in Arid Land Research Center, Tottori University:

1- Water and Agricultural Related Challenges for Sustainable Development in Egypt, May 14, 2009.
2- Agricultural Development in Egypt -Scenarios and Strategies-, August 11, 2009.
3- Design and Evaluation of Surface Irrigation System, January 20, 2010.
4- Desertification from the viewpoint of water resources in Africa, February 12, 2010.

International Conferences and Symposiums:

1- *International Conference on Water Conservation in Arid Regions* in Jeddah, Saudi Arabia, on 12 to 14 October 2009, and presents a paper with title: On-Farm Irrigation Water Management in the Nile Delta
2- USCID's *Fifth International Conference on Irrigation and Drainage* in Salt Lake City, Utah, U.S.A., on 3 to 6 November 2009, and presents a paper with title: Water and Agricultural for Sustainable Development of North Sinai, Egypt.
3- *GCOE-ARS Workshop on Science and Education Programs*, DPRI, Uji campus, Kyoto University, Japan, on 12 and 14 January 2010, and presents a paper with title: Monitoring and evaluation of irrigation improvement project (IIP) to improve the irrigation use efficiency in Egypt.
4- *3rd International Symposiums as a part of Tottori University Internationalization Project*, North-western Center for Biological Research, La Paz, Mexico from February 17-20, 2010, and presents a paper with title: Desertification and Land Degradation from the Perspective of Water Resources Management in African Countries
5- *International Symposiums on Water Issues in the Middle East and Asia* in Tokyo (March 6, 2010) and Kyoto (March 8, 2010), Japan and presents a paper with title: Water Availability and Management for Sustainable Agricultural Development in Egypt

Title of articles:

1- Estimation of applying different techniques for rice growth under drip irrigation system.

(Editing and analysis is running)

2- Effect of blast furnace slag and water purification sludge on rice growth and yield.

(Editing and analysis is running)

3- Irrigation improvement assessment from the water quality and human health perspective in the Nile Delta.

4- Water Management for Sustainable Agricultural Development of North Sinai, Egypt.

(Submitted and now under review)

5- Assessment of Cost-Effective Alternatives for Improving Irrigation Systems.

(Submitted and now under review)

6- A New Technique for Saving Water Applied under Different Subsurface Drainage Statuses for Cotton.

(Editing and analysis is running)

7- Shallow Groundwater Contribution for Jatropha Water Use under Emulated Arid Land Conditions.

(Further experiments is running now, then we will submit the results to the suitable journal for publication)

Result of research conducted:

Article 1: Estimation of applying different techniques for rice growth under drip irrigation system

The current study has been designed with the objectives to (1) investigate the relation between water input (soil water content) and rice yield, (2) clarify the benefits of adding manure on soil water content and rice yield, (3) suggest and recommend the suitable irrigation techniques (system, water content and irrigation time) to optimize the rice water use efficiency.

Article 2: Effect of blast furnace slag and water purification sludge on rice growth and yeild

Continuous and ignorant applications of bio-waste to agricultural lands are posing severe threats to the environment. Non point source of phosphorus (P) contamination is endangering shallow ground water and drinking water bodies in many part of the world. Most of the waste management strategies focused on to prevent the soils to become polluted but our knowledge is very scarce about the soils which are already polluted. Therefore, it is needed to work out new strategies to protect the environment from the soils which are already polluted. In this study some waste materials (Blast furnace slag (BFS) and sludge from water purification plant (WTR) were tested to enhance the soil P retention capacity under soil plant system and their potential effect on plant growth, yield and nutrient uptake.

This experiment will give us insight that how the application of these amendments affect the plant growth under different soil moisture condition. We would be able to know the effect of these amendments on the P mobility from the soil and plant response. On the basis of which we would be able to classify the materials as highly efficient, efficient, or non-efficient.

Article 3: Irrigation improvement assessment from the water quality and human health perspective in the Nile Delta

Optimizing the use of available water resources in dryland countries such as Egypt, through improved irrigation system, would not only enhance yields and quality of crops, but also help in avoiding water-borne diseases. Recognizing all aspects of the water resources in designing the irrigation system can lead to increased agricultural production and water use efficiency and provide more health benefits. Although the values of physical analysis parameters and heavy metal content of water in both improved and unimproved irrigation scheme areas are under permissible limits for irrigation, additional treatment is necessary at the household level for domestic water use. For multi-purpose water use, water quality guidelines are particularly insufficient. Involving farmers in different irrigation management programs, i.e. through water user associations, which will be responsible for operation, repair and maintenance of irrigation systems, would help to prevent the negative impact of environmental pollution. There is an urgent need for the education of women and children about dealing with available water resources. The term water resources for multi-purpose usage must be more widely popularized amongst the policy makers and the awareness about its consequences for agriculture, health and environment should be enhanced. Finally, more studies are needed to provide quality guidelines for multiuse of the limited water resources under arid land countries.

Article 4: Water Management for Sustainable Agricultural Development of North Sinai, Egypt

The consumption of wheat in Egypt has increased by 4% from 2006 to 2008 and demand has been met by increasing imports by 7%. To augment domestic wheat production, there is a need to include wheat in the crop rotation now to be recommended to the farmers in the NSDP area. It is expected that such an introduction of wheat in the project area will result in a production of 391,000 tons of wheat each year. Also, the cropping pattern will have to be reviewed and readjusted every few years based on the socio-economic, food security and water resource availability in the Project area. For the rapid and lasting development in NSDP area, it is recommended to revise the allocation policy for the reclaimed lands and increase the percentage allocation for the small farm holders over the level originally planned in the project. The results obtained in this study can be have useful application in projects in such areas as along the Amu Darya River in Aral Sea basin, Indus and Ganges basins in Indian subcontinent, and San Joaquin Valley, in California, USA.

Article 5: Assessment of Cost-Effective Alternatives for Improving Irrigation Systems

This study involved assessment studies to evaluate some of the cost-effective techniques for irrigation management and systems to improve the irrigation efficiency in Egypt. The following suggestions derived from the current study results will help to improve the existing irrigation system: (1) crop pattern is the most effective factor that influences the amount of applied water, irrespective of the location of the farm on the irrigation canal (head, middle, or tail); (2) equity of water distribution and crop water requirements can be met through reducing pump discharge rate; (3) decreasing the pump discharge rate led to an increase in the number of irrigation events at night, which helped maintain sufficient level of water in the canal without loss of fresh water into the drain canal and; (4) application of new techniques such as electric pump helped to reduce the operational and total costs. Therefore, alternative methods are cost effective in addition these alternatives improved the physical infrastructure of the scheme.

Article 6: A New Technique for Saving Water Applied under Different Subsurface Drainage Statuses for Cotton

This study was designed with main objective to develop and improve the traditional irrigation system as well as improving the water use efficiency for cotton. The cotton crop (Gossypium hirsutum L.) was irrigated using furrow irrigation system; this system was selected because it is widely used by farmers in the study region. The main treatments are: (1) experiments with subsurface drainage (WS) and (2) experiments without subsurface drainage (OS). Under each subsurface drainage status, the sub-treatments were using strips of furrows 60 cm wide (control), 70 cm wide (including double plants on the furrow with 1.7 times plant density) and 80 cm wide (including double plants on the furrow with 1.5 times plant density).

Article 7: Shallow Groundwater Contribution for Jatropha Water Use under Emulated Arid Land Conditions

Laboratory experiments were conducted using tunnels and weighting lysimeter in glass dome building (Arid Dome) of the Arid Land Research Center, Tottori Univ., Japan. The weighing lysimeter is a cylindrical column of 79.8 cm diameter and 120 cm height. Tottori dune sand is uniformly packed to 1.55 g/cm^3. Wind speed, air temperature and relative humidity are monitored, and these conditions are controlled based on 5 years average data from coastal area of Egypt as an example of arid land. Three columns were used with different water salinities, Jatropha sources (Kenya and Tanzania). Three sets of thermometer, tensiometers, soil moisture sensor and soil salinity sensor were installed at five depths (i.e. 5, 15, 25, 45, and 65 cm) in all columns. The aim of this research was to illustrate the Jatropha water relations as affected by shallow (fresh and saline) groundwater under emulated arid land conditions.

Dr. Majed Mahmoud Mohammad ABU-ZREIG (Soil and Water Engineering)
September 2009 – March 2010
Department of Biosystems Engineering, Jordan University of Science & Technology, Jordan
Title: The influence of soil type and rainfall intensity on the efficiency of sand ditch water harvesting

Summary of Research Activities:

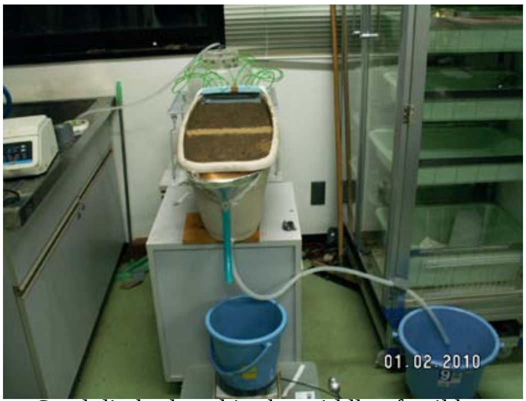
Water resources in arid and semi arid land are threatened by an increasing water demand, the stresses of water use for various activities, desertification, global warming and climate change. Groundwater quantity and quality are deteriorating rapidly due to intensive aquifer pumping at a rate far exceeding its renewable recharge. It is therefore vitally important to develop and manage water resources in arid and semi-arid regions in a sustainable and integrated manner.

Water resources management in arid land should focuses on increasing water supply while decreasing water demand and losses. Means to increase water supply are numerous including surface water harvesting and artificial groundwater recharge. On the other hand reducing water demand can be achieved by improving the efficiency of irrigation water since most of developing arid countries use more than 70% of their water budget for irrigation. For that reason, I have conducted three experiments; two experiments focus at increasing groundwater recharge thus improving water supply and the other at improving irrigation efficiency thus reducing water demand.

Experiment 1: The influence of soil type and rainfall intensity on the efficiency of sand ditch water harvesting

Surface and rainfall water harvesting at various scales is being practiced in arid and semi-arid countries such as Australia, China and Jordan to increase water supply and combat desertification including floodwater harvesting and on farm micro and macro catchment methods. Harvested rainfall can be stored in storage tanks that can be expensive and collected water is subjected to high losses due to evaporation. Other solution is that collected rainfall can be stored directly into soil profile to increase soil-water storage for crop production eliminating the need for storage tanks. A new rainfall harvesting technique, called sand ditch that allows rainfall to rapidly entering soil profile has been tested under laboratory conditions at the laboratory of Arid Land Research Center.

Sand ditches method consists of constructing a ditch across the slope of the land and is filled with local sand and fragments of sedimentary rocks that have high permeability. Due to its high infiltration rate, sand ditches permits large amount of water to enter soil profile directly from rainfall and by obstructing runoff from up-slope. The infiltrated water will then slowly seeps to the adjacent clay soil through the side of the sand ditch thus improving soil moisture condition and crop yield. Sand ditch technique can also enhances localized groundwater recharge by improving the ability of surface soil to transport water deeper in the soil profile and in short time and eventually improve ground recharge potential. Therefore, the objectives of this study is to examine the sand ditch technique as a mean to facilitate surface infiltration, reduce evaporation and ultimately improve groundwater recharge in arid and semi arid areas.



Sand ditch placed in the middle of soil box

Materials and Methods

Experiments were conducted using plastic boxes of 60 cm long, 20 cm wide and 25 cm deep. A drainage layer consists of 2 cm thick plastic mesh were placed at the bottom of the boxes to collect drainage water to an outflow pipe that was installed at bottom side of the boxes as shown in the Figure. The boxes were compacted with two types of soils, Red and Black using two compaction levels resulting in low and high bulk densities. Tottori sand ditches was placed in the middle of some boxes using constructed rectangular parallel plates of 6 cm apart that were placed tightly across the middle of the box during soil compaction. The sand ditch was 6 cm wide and has similar width and depth of the soil box. A runoff collection funnel was attached at the down slope end of the boxes to collect runoff and sediments.

The experiments were conducted using simulated runoff at a constant rate for each experiment ranging from 300 to 400 l/min supplied from the upslope end of the boxes using distributed needles and a peristaltic pump. Runoff and drainage rates in L/min were monitored at various time intervals during the experiment.

Experiment 2: Field experiment to evaluation of sand ditch water harvesting technique

The objective of this research is to evaluate the effect of sand ditch-water harvesting technique on rainfall infiltration, runoff and soil erosion under field conditions using field plots having various slopes and soil depth. Eight plots of 2 m by 10 m were constructed in the field inside the campus of Jordan University of Science and Technology/Jordan as shown in the Figure. Barrels of 130 L capacity were installed at the end of each plot for runoff collection. Sand ditch of 100 cm wide, 80 cm deep and 200 cm long was constructed in the middle of the plots across it slope. Soil was dug out and filled with sand and small gravel until it became leveled with the soil surface. Four plots were used as a control (without treatment). Ec5 moisture sensors were installed in the middle, 1 m and 2 m away from the sand ditch at 4 depths, 15, 30, 45 and 60 cm below soil surface for one sand ditch plot. The control plots had 3 Ec5 sensors installed in the middle at 20, 30 and 60 cm below soil surface.

Experiment 3: Improving irrigation efficiency by using ceramic pitchers.

Pitcher irrigation is a traditional irrigation method that has been practised in many parts of the arid world such as Iran, Africa and South America. Water is distributed from unglazed baked earthen pitchers buried in the soil. Pitchers gradually release water through their porous walls into the root zone by the action of static pressure and soil suction pressure. The outflow of water is affected by many factors including the saturated hydraulic conductivity of the pitcher material, wall thickness, surface area, type of soil, type of crop and rate of evapotranspiration. Pitcher irrigation is claimed to be a self-regulative system with high water saving potential and good capabilities for irrigation of various types of crops Despite its apparent simplicity, factors affecting the system performance have not been well described and analyzed in the literature. The objectives of this research are to estimate seepage rate of pitchers as affected by their saturated hydraulic conductivity, potential evaporation and soil.

Materials and Methods

Seven pitchers of varying volume and production process were selected from local producers in Jordan and imported to Japan. The average volume, height and maximum outside diameter were about 1280 ml, 24 cm and 14 cm, respectively. The saturated hydraulic conductivity of pitchers was measured with constant head method. A pitcher was placed in the atmosphere and the outflow rate of pitcher was measured under constant head maintained with Marriott bottle arrangement. The saturated hydraulic conductivity was estimated by applying Darcy's law on the outflow rate of the pitcher at constant head condition.

Two sets of experiments were conducted to measure seepage rate of pitchers in a closed chamber under controlled temperature and humidity in the free air and inside soil. The soil used in the experiments was Tottori sand. Pitchers in the air or inside soil were filled with water, placed inside the chamber and the loss in their weight was recorded every 24 hours for two days. The temperature and humidity inside the chamber were varied to quantify the influence of evaporation potential on pitcher's seepage rate in the air or when buried inside soil.

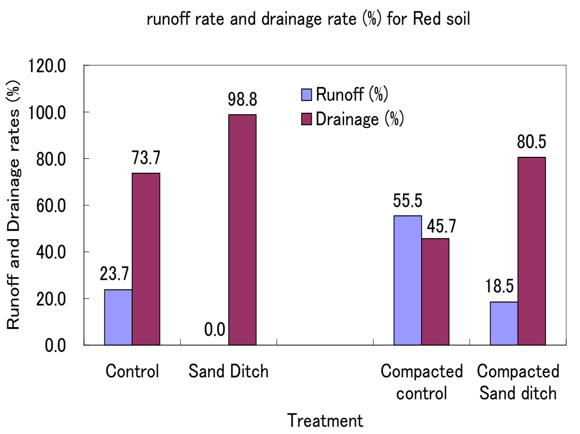
Title of Articles:

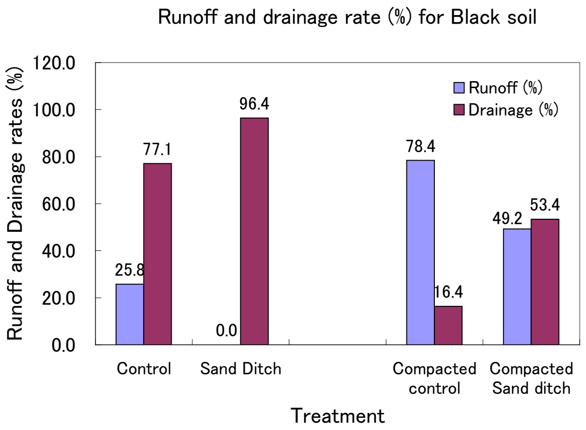
- The influence of sand ditch on water runoff and drainage. To be submitted for publication
- Field evaluation of sand-ditch water harvesting technique. To be submitted for publication
- Pitcher seepage rate as affected by evaporation. To be submitted for publication

Result of Research Conducted:

Experiment 1:

Results indicated that sand ditch have profound effect on runoff and drainage rate and volume in both soils. In the control soil plots having low bulk density, the average runoff volume from the Red soil and Black soil plots were equal to 23.7% and 25.8%, respectively. However, No runoff was observed in the sand ditch plots for both soils as shown in the two Figures below. Sand ditch was able to eliminate runoff and apparently all inflow water was infiltrated in the soil before reaching the outlet. Consequently, drainage rates and volumes in the sand ditch plots for both soils were significantly higher compared to control. The average drainage rates as a percentage of the inflow rate in the sand ditch plot for both soils was 98% compared to only 75% in the control plots. The effect of sand ditch on compacted soil was even higher than that in normal density soil. The average drainage rate percentage from the inflow rate in the sand ditch plots for compacted red soil increased from 45.7% for the control plots to as high as 80.5%. The correspond increase in the compacted black soil were 16.4 for control to 53.4 for the sand ditch plots. These results show that sand ditch technique can profoundly enhance rainfall infiltration and increase drainage water thus improve soil moisture content for crop production and enhance the potential of groundwater recharge.



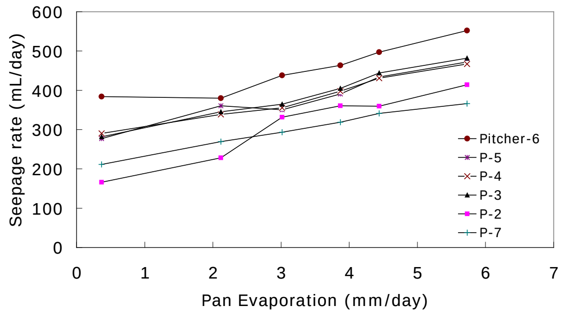


Experiment 2:

The results of this experiment, including runoff depth and sediment loss for each rain storm along the season and soil moisture variations will be collected in May, 2010 at the end of the rainy winter season. The influence of sand ditch on water infiltration, runoff and soil loss will be quantified by comparing these parameters with that for control plots.

Experiment 3:

The saturated hydraulic conductivities of pitchers varied widely depending on the type of materials from which pitchers were made and the manufacturing conditions. The variability was well demonstrated in the free seepage of pitcher in atmospheric conditions. The free seepage volume of the pitchers, under atmospheric pressure and falling head conditions, varied from 160 to as high as 400 mL/day depending indicating the variability of the manufactured materials.



Variation of pitchers' seepage rate with pan evaporation

However, this seepage increased markedly under conditions of high evaporation potential. When pan evaporation changed from 1 to 6 mm/day in a controlled chamber the free seepage of pitchers increased in the range of 30% to 120% for different pitcher as shown in the Figure. Furthermore, when pitchers were buried inside the soil their seepage rates increased by an average of 130% compared to that in the atmosphere under similar climatic conditions.

Other Activities:

1. Attended two symposium:
   ① National joint research symposium. 8 December 2010.
   ② International symposium on dust vegetation interaction. 27 February 2010.
2. Delivered number of seminars as follows:
   ① Water resources management in arid land, ALRC
   ② Pitcher Irrigation, little is known but large water saving potential., ALRC
   ③ Sediment and pollution control with vegetated filter strips, ALRC
   ④ The influence of polyacrylamide (PAM, an organic polymer) on runoff and soil erosion, ALRC.
   ⑤ Design of subsurface drainage systems, JUST University, Jordan
   ⑥ Water and irrigation management in Jordan, ARENA, U of Tsukuba

Dr. Elfadil Elfadl BABIKER (Plant Biochemistry)

October 2009 – September 2010

Faculty of Agriculture, University of Khartoum, Sudan

Title: Fertilization and inoculation of winter sorghum: Morphological, physiological and biochemical characterization

Summary of research activities:

A. Research activity:

Low productivity and nutritional quality of sorghum are a common problem encountered in all States in Sudan. Winter and summer sorghum are among the crops grown in rural areas for local consumption. The production of winter sorghum is very low compared to summer one. Improvement of the proteins quantity and quality will make sorghum a useful source of protein as well as other constituents. Since 1992 we have been involved in research related to developing countries' crops and foods with emphasis on crops that grown in far rural areas in which people are suffering from malnutrition due to low quality and quantity of products as a result of bad environmental and soil conditions. We started to improve the crops nutritional value either by substitute the food with other ingredients or improve the soil nutrients. The basic crops involved in our research are sorghum and millets. In far rural areas (Western and Northern Regions) desert is the key problem and farmers grow such crops in valleys of low water content**.** Therefore, the nutritive value of such crops is very low due to the following reasons:

1. Poor soil fertility.
2. Adverse climatic condition.
3. Farmers usually grow crops that can resist such adverse conditions which are known to be of low quality.
4. The presence of antinutrients in large quantities in such crops.

Currently we would like to utilize valleys and desert around valleys to increase the area of production (quantity) but quality wise we are now studying different approaches to solve this problem. The main approach now is to study the effect of micronutrients on nitrogen content and physiological and morphological characteristics of different sorghum cultivars. A preliminary experiment showed that nitrogen content of sorghum can be increased significantly with improvement in some physiological and morphological characteristics as a result of micronutrients fertilization. According to the data obtained we plan to test the response of nitrogen and some physiological and morphological characteristics of four sorghum cultivars to micronutrients fertilization. In November 2009 we brought the soil and dry it for two weeks and then weighed out in 48 pots to be ready for sowing the seeds with different levels of fertilizers. Then in December 2009 the pots were transferred to the doom and planted the seeds together with the fertilizer application.

Parameters to be measured:

1. Some physiological and morphological characteristics of the plants during all the stages of plants growth.
2. Physical characteristics of the seeds and shoot of the plants.
3. Nitrogen content as well as protein content of the seeds and shoot of the plants.
4. Measurement of some micronutrients of the plants seeds and shoots.
5. Correlate the level of micronutrients with changes occurred for the parameters above.

B. Other activities:

1. Reviewing and editing scientific manuscripts of graduate students and researchers for conference and publication as well as students PhD thesis.
2. Act as a reviewer for many International Journals during this period such as: International Food research Journal, African Journal of basic and Applied Sciences, Research Journal of Agriculture and Biological sciences, Australian Journal of Basic and Applied Sciences, World Applied Sciences Journal and African Journal of Food Science.
3. Visited Sudan to attend University of Khartoum conference entitled **“**The role of Scientific Research on nation’s development” which held from February 27 to March 2, 2010. I have been awarded a prize as a distinguished researcher in the closing ceremony of the conference.
4. Visited Sudan to prepare a visiting program for a delegation from Tottori University to make a scientific relation with University of Khartoum from February 14 to March 4, 2010.
5. Visited Sudan with Tottori University delegation to sign a memorandum of understanding between Tottori University and University of Khartoum from March 27 to April 2, 2010.

(4) Project Researchers

Dr. Hisashi Tomemori (Protected Cultivation)

We conduct 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:

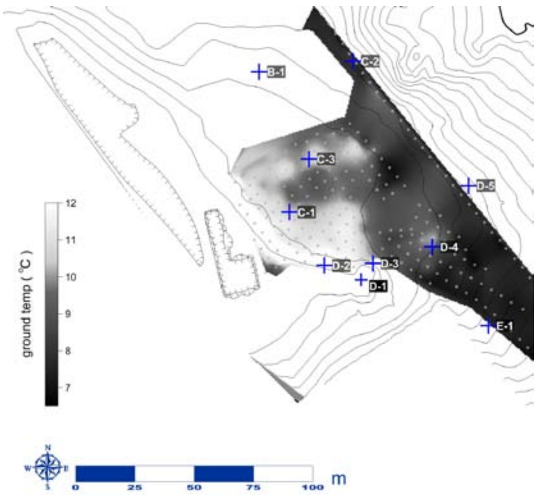
- Study on the irrigating method for the root systems of physic nut
- Low-temperature tolerance of physic nut
- Pruning method for physic nut
- Investigation and simulation for greening based on rainfall promotion

Overseas research activities during the fiscal year include visits to the National Institute for Investigation in Forestry, Agriculture and Animal Production (INIFAP) of Ministry of Agriculture, Animal Production, Rural development, Fishery and Alimentation, Mexico, for discussion about collaborative research and experiments.

Dr. Takayuki Kawai (Groundwater hydrology)

To develop new groundwater inquiry technology in sandy area, various hydrological phenomena were researched. The content of the research was to analyze the influence of sediment heterogeneity on groundwater flow with the various type of physical properties. The figure showed the result of high-groundwater flow points with 1 m deep ground temperature under same groundwater depth in sandy soil.

The main grant was 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.).



Heterogeneity of groundwater flow and ground temperature

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), the researcher has conducted analyses mainly using MODIS true color images (hereafter MODIS image) and SYNOP report, which is meteorological data observed at meteorological observatories. In this fiscal year, he carried on the near real-time dust monitoring system, which was built up last fiscal year, and he also upgraded it with the information of geopotential height. The images on the system are open on his homepage, 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), he aims 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, he made a comparison of the data distributed from the Japan Meteorological Agency, the National Climatic Data Center of the U.S., and the Institute of Meteorology and Hydrology of Mongolia, and he consolidated the data of them. Using the consolidated data, he clarified that summer precipitation amount and vegetation activities largely affect the dust emission on April in the next year at Mandalgobi, Mongolia. He reported this result on meetings, conferences, and symposiums, and the presentation held on Kanazawa appeared in a newspaper (Asahi shinbun, October 29th).

Research grants in the fiscal year include:

Clarification of the relationship between land surface conditions and threshold wind speeds of dust emission for the evaluation of wind erosion in broad area

Japan Society for the Promotion of Science, Grant-in-Aid for Young Scientists (B), 2009-2012 (Project Leader: Y. Kurosaki)

Dr. Shigeoki MORITANI (Soil Management)

The FAO/UNESCO soil map of the world reveals that the total land area of 12.8 billion ha has been affected by salinity and sodicity. These degraded soils are distributed in dry and semi-dry lands such as Australia and South America and poorly drained lowlands such as that seen around the Aral Sea. Sodic soil can be damaging to plant growth owing to sodium toxicity and a decrease in soil infiltration of water as a result of decrease in aggregate stability which in turn attributes the salt accumulation in soil. The disposal of coal fly ash, which is generated from thermal power plants, poses a serious environmental problem. Artificial zeolite (AZ) which possesses high porosity and high CEC is synthesized from this fly ash. AZ has been used to improve plant growth and soil aggregate stability as well as to control soil erosion. The use of AZ as a soil amendment could help to alleviate the environmental problem in regard to the disposal. The objective of my study was to investigate the effectiveness of artificial zeolite as a soil amendment in improving the physicochemical properties of sodic soils.

Dr. Shogo Imada (Root Ecology)

The research of the Root Ecology Subdivision is conducted to reveal the environmental tolerance of woody species in arid and semi-arid regions. In these regions, soil drought and salinity are the major factors that limit plant growth because of low rainfall and high evapotranspiration. Fine roots are essential for substantial intake of water from soil, and thus play a key role in sustaining whole-plant growth. The main plant material is a

Invasive tamarisks along the Colorado River

halophytic shrub or tree, tamarisk (*Tamarix* spp.) which is a candidate used for afforestation in degraded saline lands of native habitats, such as China. The species is also a highly invasive weed along rivers in the U.S. Comparative information of ecophysiological properties between native and invasive tamarisks can be beneficial to use the plants for afforestation in their native habitats and to control their distribution in the invasive environments.

The main research in this fiscal year was of salt dynamics and salt secretion mechanism of invasive tamarisks in a riparian forest in the Mojave Desert, U.S., and fine-root dynamics of tamarisk cuttings under different salinity conditions using a minirhizotron technique. Overseas research activities in the fiscal year included a stay in the Desert Research Institute (DRI), Nevada, U.S. to receive training and conduct field surveys (Jul. 1 to Oct. 31, 2009) and a short term visit to the DRI in order to gather field survey data and have a meeting (Feb. 15 to 27, 2010) on the global COE program.

Dr. Iwanaga, F. (Tree Physiological Ecology)

Studies on eco-physiological characteristics of plant species growing in arid area are performed to clarify the mechanism of salt and drought tolerance, and to develop stress tolerance of planting species. In general, plant species would accumulate various metabolites in response to abiotic factors such as high salinity and water deficiency. The present research deals with relationships between these compounds, including betaines, sugars, and amino acids, and characteristics of individual distribution and growth pattern of plant species in arid area.

In this fiscal year, investigations are carried out with herbaceous and woody species growing under drought and/or saline condition, including *Tamarix ramossissima* as an important invasive alien species in the eastern part of the U.S., in the joint research program with Desert Research Institute, Nevada, US.

Dr. Erdenebayar MUNKHTSETSEG (Agricultural Meteorology)

Interactions between vegetation activity and land surface processes

Dr. Yunxiang Cheng (Plant Ecology)

The Plant Ecology conducts research on understanding and predicting the main drivers of plant community composition and species richness in arid and semi-arid lands. Especially, it is important to clarify the interaction between plant communities and environmental condition. Droughts frequency have become increasing in these years, particularly in Mongolia. Evaluating the impact of the drought to plant communities is important not only for comprehending the relationship between vegetation and dust emission, but also for overall ecological correctness. The main research topics in the fiscal year were as follows:

- Impact of rainfall variability on plant diversity in grazing land of Mongolia
- Plant communities of Great Gobi A Strictly Protected Area, Mongolia

The main fellowship grant was as follows:

The global center of excellence program for dryland science of Tottori University

Dr. Andry Henintsoa RAVOLONTENAINA (JSPS Postdoctoral Fellow)

Effects of Carboxymethylcelluloses on Some Hydraulic Properties of Sandy Soil and Tomato

Growth

Over the past decades, there has been rapid increase in human population. This has resulted in increased demand for food, fiber and raw materials to meet human needs hence there is an urgent need to intensify agricultural production to secure food supply for the increasing population. As a result, the agricultural sector has become more intensified over the past few decades leading to increased land use pressure. Sandy soils are been brought into cultivation leading to irreversible soil degradation, increased environmental risks and sustainability problems associated with farming in a poor soil. Most sandy soils are currently being used for vegetable production in regions where land availability is a big problem to farmers. Sandy soils are characterized by low water-holding capacity and excessive drainage of rain and irrigation water below the root zone, leading to poor water and fertilizer use efficiency by plants grown on them. Seed germination and plant development are critically restricted because of low soil moisture content. Furthermore, the problem becomes accentuated when plants with shallow rooting are grown. The efficiency of the use of rain and irrigation water by plants is of great importance in semiarid and arid regions, where shortage of water is frequently experienced and water is often the limiting factor determining the size of the cultivated area.

A possible means by which water loss due to drainage within sandy soils could be prevented is to mix the soil with a hydrophilic polymer (e.g., cross-linked polyacrylamide with high molecular weight and high negative charge) that is capable of swelling and retaining water up to 500 times its own weight (Kazanskii and Dubrovskii, 1992; Xu et al., 2006). To date, however, the use of superabsorbent polymers as soil additives has gained limited acceptance, possibly because results from studies on their benefits in improving crop yields and saving water have been mixed. Some studies have shown that the addition of superabsorbents reduces the sensitivity of plants to water shortage and increases crop production (Viero et al., 2002; Rowe et al., 2005). Other studies, however, have either reported no saving of water (Ingram and Yeager, 1987) or that there were detrimental effects on plant survival and yield (Green et al., 2004).

Following the uncertainty concerning the efficacy of superabsorbents in improving the water regime within sandy soils, the objective of my study was to examine, in both laboratory and greenhouse field, the effects of four carboxymethylcelluloses (CMC), mixed at various rates with a sandy soil, on the water-holding capacity and hydraulic conductivity of the sandy soil when leached with distilled water (simulating rain), tap water, and saline waters and on the tomato growth. Our experimental results show that:

1-The maximum water absorption of the CMCs ranged between 80 and 100 kg kg^{-1} of polymer, however, the absorbent swelling capacity decreased significantly (P <0.05) with increasing salt concentration in the solution. The water absorption capacity of the CMCs decreased significantly (P < 0.05) when incorporated in the sandy soil compared to that of the absorbent alone. It was found that application of CMC increased significantly (P <0.05) available water content up to 3 ±0.5 times to that of control soil. Water retained per kilogram of absorbent increased with increasing grain size and absorbent concentration in the soil-absorbent mixtures.

2-All soils treated with CMCs showed a significant decrease (P <0.05) in K_S compared to the control soil. And, K_S was found increased with increasing the salt concentration in the leaching solution. The reduction in K_S of soil-absorbent mixtures following leaching was controlled mainly by the polymer swelling capacity, which is in function to their water soluble property and salt absorption capacity. As a result, the effect of rainfall on K_S is generally affected by the irrigation water quality.

3- The water use efficiency increased significantly (P <0.05) with increasing the absorbent concentration in the soil-absorbent mixture. This result was attributed to the improvement of both in water retention and nutrients retention of the sandy soil after absorbent incorporation.

Use of water absorbents in sandy soils from arid and semi-arid regions could serve as an important tool in increasing water-use efficiency and crop production. It should be born in mind, however, that when calculating the amounts of absorbents needed for field application, the effect of irrigation water quality used on their swelling capacity within the soil matrix should be taken into account.

Dr. Bouya Ahmed OULD AHMED (JSPS Postdoctoral Fellow)

Irrigation management options of saline water for sustainable agriculture in arid land

Research background:

My research background was to investigate the 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. The research also was investigated how to increase crop production in arid land area using poor quality water as well as the managements of salt accumulation.

Research methodology:

During my period three different experiments were carried out under greenhouse condition at Arid Land Research Center (ALRC). Water content and salinity of soil were measured simultaneously by sensor. Saline water irrigation combined with manures and irrigation interval was tested. Last experiment was used porous as amendment to increase water holding capacity of sand soil; this experiment was carried out in the field in Mauritania as well as in the greenhouse here in Japan. Three crops were growth during my period wheat, Swiss chard, and tomato.

Research implementation and results:

The research was basically about how to improve drip irrigation scheduling using saline water. First work was used saline irrigation 2dS m^{-1} with irrigation interval of one day and every second day in greenhouse with two manures treatment (Farmyard and poultry). This work is published in Agriculture water management journal. The result has come out with that daily irrigation using cow manure was give good result compared to other treatments. The second work which has been published in International Journal is using porous as amendment to increase soil water content. This experiment was carried out in greenhouse using two porous layers of 2 cm and 5 cm thickness placed in the soil with control treatment. Result showed that the 2 cm thickness of porous was the best treatment given good water content therefore very higher fresh yield. Result of my research was presented in three different international conference. The first one was held in Fez at Morocco, October 2008 and second was held in Jeddah, Saudi Arabia October, 2009 this conference was discussed about saving water in arid area. Last international conference held in Pittsburgh, America November, 2009.

International exchange achieved through the research:

After my gradation from Tottori University, Arid Land Research Center, I was able to publish some articles in good international journal that have impact factor such as Agricultural water management, Transaction of the American Society of Agricultural and Biological Engineering, American journal of Environment Sciences, Communication in Soil Science and Plant Analysis, and Soil Use and Management. This result was come out from my cooperation with Professor Mitsuhro Inoue. During my tenure, I was able to establish connection between the institute in of Science and Technology in Mauritania and Arid Land Research Center in Japan. Project research was about saving water in Arid Land regions using cheapest method and could achieve agricultural sustainability. As result of this cooperation, I could secure a full-time position at Institute of Science and technology in Mauritania and will continue our cooperation between this two institute supported by G-COE program or other program.

Mohamed Abd Elbasit Mohamed Ahmed (JSPS Postdoctoral Fellow)

Research was devoted to establish observational and experimental studies in order to understand the temporal and spatial dynamics of soil erosion in arid areas. Research activities during 2009/2010 are including:

1. Measurement of the rainfall micro-properties in Sudan including raindrop size distribution (DSD) and rainfall kinetic energy (KE) as cooperation with Vaisala Company (Finland), and National Center for Research (Sudan).
2. Evaluation of gully erosion in arid environment, Sudan
3. Experimental study on measurement of soil-surface changes due to tillage using low cost close range photogrammetry, Sudan.
4. Soil erosion evaluation in the Loess Plateau, China.
5. Mapping of soil erosion potentials in small watershed in the Loess Plateau, China
6. Rill quantification using close range photogrammetry, China.
7. Research on mesquite impact on water resources in arid areas, Sudan (Project of Research Institute for Humanity and Nature)