(2) Summary of Joint Research

A-1) Studies on the Micrometeorological Improvement of Agricultural Fields in Arid Lands

Studies on Characteristics of Turbulence Transfer of Heat, Moisture, Momentum and Scalar Quantity in and above Canopy under Dry Condition

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The objective of the present study is to clarify the mechanism of CO_2, water vapor and heat transfer over the field in the sand dune area. The measurement of atmospheric CO_2 concentration and micrometeorological observation were conducted in the Bermuda grass field in Arid Land Research Center. The CO_2 concentration over the coarse vegetation was strongly influenced by plant photosynthesis and respiration as well as by micrometeorological condition. Temporal increase of CO_2 concentration was observed at the transition of sea and land breeze, which was suggested to be a general phenomenon on the coastal field in the arid land of cool climate. Water use efficiency of sorghum on nonirrigated field decreased to about 50 % relative to that of irrigated field, and it was found that sorghum suffered water stress.

Estimation of Soil Moisture in the Shallow Root Zone Using Simple Meteorological Observation

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Soil moisture content of a shallow root zone (40cm in depth) at Tottori sand dune was predicted by modified Nakayama model (Nakayama et al., 1991). The original model describes the soil moisture content of Kanto loam using routine meteorological data which were air temperature, wind speeds, duration of sunshine and precipitation. We modified the model for fitting the sandy soil and compared this result with the observed value in 1998. The observation of soil moisture was carried out from Mar. 16 to Aug. 26, 1998 by using FDR. The improved parts were as follows;

1) Introduction of Duration of raining: The original model assumes that soil moisture content will decrease to field capacity in one day after the rain but sandy soil decrease to it more rapidly than loam. We considered this characteristics of sandy soil and added the duration of raining to the model as a factor. This diminished the prediction error of soil moisture content by 4 mm at the maximum.

2) Omission of Capillary flow: The upward capillary flow for the root zone was 0.00162mm/day at the maximum. We can ignore this term in the water budget because it is relatively smaller than other terms. This enables the model to predict soil moisture content without unsaturated permeability.

The modifications above two parts improve the prediction of soil moisture content by 0.4mm/day on the average in 1998.

Studies on the Micrometeorological Improvement of Agricultural Fields in Arid Lands
- Measurement of Evapotranspiration in Arid Fields by Micrometeorological Method -

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The measurements of micrometeorology and soil water movement were done in a grassland field at Arid Land Research Center, Tottori University, from the end of August to November, 1998. The water movement and the rainfall and pan evaporation were measured automatically by ADRs and a electric balance, respectively. The evapotranspiration in fine days was about 3mm/d until the middle of September, and after that time it decreased to 2 mm/d. The distribution of heat fluxes at the soil surface was different according to the amount of rainfall and irrigation and the condition of vegetation growth. The sensible heat flux was relatively large at the first stage of measurement when the grassland vegetation was sparse. However, the output of heat fluxes almost amounted to the latent heat flux when the vegetation became dense, and the sensible heat flux increased, in spite of dense vegetation, at the last stage when the field was relatively dry.

A-2) Hydraulic Design and Water Management of Microirrigation

Water Dynamics in Citrus Tree

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The objective of this study was to examine the effects of NaCl on transpiration of citrus tree. Measurements were made on citrus trees raised in lysimeters in a greenhouse on 15 September, 1998. A citrus tree was irrigated with tap water (control), while another was irrigated with 2000mg/l NaCl. Transpiration from each tree was measured at the trunk with the heat balance sap flow sensors every 30 min. There was no significant difference in diurnal change in transpiration between the two trees, that is, diurnal change in transpiration of the salinised plant was not effected by NaCl in this experiment.

Studies on Water Requirement of Several Fruit Trees

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Information on the water requirement of fruit trees is essential to grow them in arid-land agriculture where effective use of water is required. In this study, the water requirements of two-year-old trees of grape cv. Kyoho and Delaware were investigated in a plastic greenhouse. The material plants were grown in pots

and each pot was covered with polyethylene films to prevent surface evaporation. Transpiration amount was calculated by subtracting drainage amount from irrigation amount during the growth period. Net production was the difference between the total dry matter of tree including fruits and litter before leaf fall and that of tree before bud-burst. Water requirement of Kyoho was 250 ml in the growth period whereas that of Delaware was 150 ml. In the case of Kyoho, water requirement of two-year-old tree is smaller by 120 ml than that of the nursery stock.

Chemical Injection System in Microirrigation using Bend Pipe

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In this paper, the hydraulic characteristic of chemical injection system using the bend pipe was clarified. The outside and inside parts of the bend pipe were connected by the pipe. In this route, the bypass water flow is generated by the centrifugal force of flowing water in the curved main pipe. The hydraulics of water flow in bypass route of the curved pipe is characterized by the centrifugal force line. The relationship between main pipe flow and bypass flow rate is discussed, and the hydraulic design procedure of chemical injection system using the curved pipe with bypass flow is also described.

A-3) Analysis of the Eco-physiological Characteristics of the Root System under Arid Land Condition

Analysis on Water Absorption by Root Systems of Cereal Crops with Reference to Their Morphology and Anatomy

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Structure and function of root system were studied in cereal crops to improve their production under stressed conditions. (1) Bleeding rate of field-grown maize was measured to evaluate physiological activity with reference to water absorption. Bleeding rate increased with growth stage to reach the maximum value at around tasseling stage and rapidly decreased thereafter. Water absorption indicated by bleeding rate was affected by morphology of whole root system (especially number and diameter of nodal roots) as well as physiological activity of each roots. (2) Then the pathway of water into and in individual root of both maize and wheat was analyzed by fluorescence microscopy after feeding fluorescence dye. The results suggested that barrier for apoplastic pathway was not only in endodermis but also in exodermis in maize. Root tip, however, has no such barrier in both endodermis and exodermis. (3) Silicon which might be related to drought tolerance was examined in seminal roots of rice cultivars by scanning electron microscopy with X-ray analyzer. Silicon deposition was significant especially in cell wall of endodermis. The amount of silicon increased basipetally where it might has an intimate relationship to drought tolerance.

Sudden Increase of Exudation Rate in Corn Plants Suffered Soil Desiccation by Irrigation

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Drastic increase of exudation rate after irrigation is observed in maize suffered long term soil desiccation. Our objectives are to clear why suddenly the exudation rate increases. One corn plant, Pioneer 3540, was planted in pots containing sands and grown with hydroponics. At 60 days after sowing pot sands were washed by water to remove hydroponics solution, irrigation was restricted for eight days and abundant water or hydroponics solution were applied to pots. Exudation rate (ER) calculated for sap gathered from cut stems and osmotic potential (OS) of the exudation, started to increase within a half day after the irrigation and indicated the maximum rate in both (water and hydroponics) irrigation treatments, decreased one day after and was maintained in the level as same as that before irrigation for four days. There was a close relationship between the ER and the OS. Even if water with very low concentrations of nutrients was irrigated, the exudation sap contained higher concentration of N, K and other nutrients than that of the applied irrigation water. We suggested that sudden increases of exudation rate after irrigation in dehydrated maize accompanied increased OS to be resulted by accumulation of osmotic substances in the root under soil desiccation.

Root Growth and Viscoelastic Properties of Cell Walls Mediated by the Water Environment

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The water environment of roots such as ion balance, pH and drought strongly affects root growth. We analyzed the effect of low pH on the viscoelastic properties of root cell walls. We used the creep method and measured viscoelastic physical parameters of root cell walls in *Pisum sativum* L. as influenced by low pH. We found that the viscoelastic properties of the root could be expressed by the six physical parameters of elastic moduli and of viscosity coefficients. We also tried to identify the location of extensible part along root axis by one-mm distance from the root tip. The technical development enabled us to measure the extensibility of every one-mm distance from one-mm behind the tip towards the base of lateral roots. The cell wall extensibility was highest at the 2-3 and the 3-4 mm zone and then rapidly declined towards the base. The extensibility of the cell walls was parallel to the decrease in the elastic moduli and the viscosity coefficients. Low-pH treatment of the cell walls *in vitro* remarkably decreased the viscosity coefficient. Thus we suggest that the low pH-induced increase in cell-wall extensibility is mainly due to the decrease in the viscosity coefficient.

A-4) Studies on Water-Saving Cultivation of Crops in Arid Lands

Isolation of Frankia-like Actinomycetes from Nodule-lobes of Casuarina Roots in Ishigaki Island

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Casuarina trees are one of actinorhizal plants, and fix dinitrogen in root-nodules infected by Frankia actinomycetes.

Root-nodules of Casuarina trees were sampled at the seaside of Nagura bay, Ishigaki island. Lobe-tops of the nodules were separated, surface-sterilized, and homogenized. The homogenized suspension was filtrated through jointed 60 μm and 30 μm mesh-filters. The filter meshes were rinsed. The trapped actinomycetal mycelia were collected and diluted in 1% agar Frankia medium. Every 3ml of the diluted suspension was spread on the pre-fixed 1.5% agar medium plates. After 2 month-incubation, actinomycetal colonies were picked and transferred on Frankia medium plates. After 2 month-incubation, morphologically different actinomycetal colonies were isolated to 5ml BAP liquid medium, and homogenized. Every 1ml of the homogenized suspension was inoculated to 9ml of liquid medium. After 1 to 2 month-incubation, the colonies were microscopically observed.

Morphologically different 8 actinomycetal isolates (strains Ishigaki-1 to Ishigaki-8) were obtained. Frankia-specific "sporangium" was not observed yet, while Frankia-specific "vesicle"-like or spherical node-like organs were observed. (However, they were not well-developed clear "vesicles" with thick cell membrane.)

An inoculation test of the Frankia-like actinomycetes to Casuarina seedlings under controlled conditions is required to confirm nodule formation.

Effects of Salt Water Irrigation on Growth of Bulbous Plants

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Effects of salt concentration in irrigation water on growth of bulbous plants were investigated. Bulbous plants of five families, 21 genera and 36 species/cultivars were planted in plastic pots on 31 August or 27-28 October 1998 and grown in a greenhouse. 0, 500, 1,000, 5,000 mgl^{-1} salt water was applied when watering. Eight plants were used for each treatment.

Although the complete data have not been obtained since some plants are still growing by the end of April, generally up to the concentration of 1,000 mgl^{-1} either the days to flowering or the plant height of many of the species/cultivars were nearly the same among the treatment. Plant height was shortened and flowering was delayed at the concentration of 5,000 mgl^{-1}, but still alive.

A-5) Eco-physiological Studies on Tree Tolerance to Water Deficiency and Salinity

An Ecophysiological Study on the Mechanism of Drought Damage of Trees

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Since drought damages are complex effects involved by the dehydration of tissues, high temperature and strong radiation, the total consideration is needed for prediction. Here, we present the predicting model of drought damage integrating species characteristics and environmental conditions.

The model was composed of the sub-models of evapo-transpiration, plant moisture, soil moisture and heat budget of leaf. The under-ground structure was composed of multi-layers. The water uptake was regulated by the gradient of water potential and the hydraulic resistance of soil-root interface. The transpiration was regulated by the gradient of vapor density and the resistance of canopy and boundary layer. The simulated water potential and the leaf temperature were compared with the critical value of heat and drought injury and the point when the severe stress of heat and drought are caused was evaluated.

On the assumption of physiological parameters of *Populus alba*, heat injury was caused on the higher air temperature than 38℃. If the LAI of the stand of *Populus alba* is 6 and available soil thickness is 50cm, drought damage was caused after 2 weeks of rainless period. These results were well fitted to the observations past reported.

Studies on Salt Tolerance of Tree Species

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The behavior for the salinity was studied using an Okinawan mangrove tree, *Bruguiera gymnorrhiza* in a greenhouse at University of the Ryukyus, Okinawa. The viviparous seedlings of *B.gymnorrhiza* were controlled under non salt water condition about ten months, after that all the seedlings were controlled under the quarter salt concentration of the sea water for the next two weeks. The seedlings were separated into three groups: 1) twenty seedlings under 3.6 % salt water condition, 2) twenty seedlings under 1.8 % salt water condition and 3) twenty seedlings under non salt water condition. After two weeks pretreatment, the seedlings in all groups were controlled under 10 % salt water condition.

At the 7th day after high salt water treatment, survival rates of leaves were about 85 % in the 3.6 % salt water condition and about 65 % in 1.8 % and 0 % salt water conditions. After that the survival rates were decreased gradually, and those were reached 0 % until twenty days after the high saltwater treatment. At the 10th day after the salt water treatment, the rates of photosynthesis at high light flux were 17 μmol/㎡・s in the 0 % salt water, 13 μmol/㎡・s in the 3.6% salt water and 12 μ mol/㎡・s in the 1.8 % salt water condition. At four weeks after the salt water treatment, the order of those rates changed, the highest one is 12 μmol/㎡・s in the 3.6 % salt water and the lowest one is 6 μmol/㎡・s in the 0 % salt water condition. And at the second day after high salt water treatment, the rates of photosynthesis were nearly zero in all the groups. These behavior were compared with the experimental results on salt tolerance of *K.candel* seedlings. The result was that salinity tolerance of *K.candel* was stronger than that of *B.gymnorrhiza*.

Growth and morphology of *Salix psammophila* planted on slopes of sand dunes in the Mu Uu desert, China

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The growth and morphology of *Salix psammophila* planted on a slope of a sand dune to control the movement of sand in the Mu Su desert, China were investigated in August, 1998. A rectangular plot (3m in width x 18m in length) parallel to the slope was established in the plantation of *Salix*. The plot from the base to the top of the sand dune was separated into 6 small plots (3m x 3m). The small plot located at the base of sand dune was adjacent to a swamp grass field. For all plants in the plot, tree heights, stem diameters, branch numbers, biomass above the ground, leaf morphology and the stomata density of leaves were determined. The growth and average biomass of the plants were the greatest in the small plot at the top of the sand dune and decreased as the location of small plots lowered. These results suggest that this species is tolerant to drought condition, but not adaptable to swamp field.

A-6) Studies on Farm Land Conservation in Arid Areas

Research on Measurement of Hydraulic Properties for Conservation of the Shallow Groundwater.

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A new parameter estimation methodology of determining unsaturated soil hydraulic properties from laboratory or in-situ transient outflow experiments was investigated. In this method saturated hydraulic conductivity and unsaturated soil hydraulic properties in van Genuchten's equations are estimated by Genetic Algorithms (GA) incorporating finite element solution of Richards equation. GA is one of the increasingly popular global optimization methods. Our proposed method based on GA has some advantages over some more traditional gradient-based method. Because it does not need to calculate derivatives of objective function, it is simple to use and also very stable and robust.

Measured soil water pressure and cumulative outflow data as a function of time were used to evaluate the objective function. The utility of our proposed method is demonstrated using experimental data for Japanese sandy soil. An excellent agreement between optimized and independently measured soil water retention data and saturated hydraulic conductivity were found.

On the Characteristics of Rill Patterns Generated on the Salinity Soil
-Time Variation of Plane and Sectional Patterns of Rills and Sediment Rate out of the Slope -

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In order to estimate the sediment rate from bare salinity slopes, it is important to know the relationship between the characteristics of run-off and the geometric properties of rill patterns. As a first stage of this study, experiments were carried by using artificial model slope while supplying water flow on the slope. Model slope was composed of only clay and sandy soil, not salinity soil. The ratio of clay to sand was 0,3,5,10%. The time variations of sediment rate were measured. As well, time variations of plane and sectional patterns of rills was measured. As a results of experiments, after the first ten minutes had passed, it is clear that the position of the watercourse was settled and erosion proceeded in the vertical direction. The plane and cross sectional patterns of rill may change rapidly during the first few ten minutes and thereafter they may change slowly. Observation has shown that the plane and cross sectional patterns were more complex as the ratio of clay soil was increased.

Preferential Flows and Solutes Transport in Sandy Soils

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Fingered flow caused by wetting front instability may enhance solute leaching to the groundwater. Little is known about the nature of the flow directly below the soil surface (the induction zone), where infiltrating water moves laterally towards the fingers. The behavior of fingers when they reach the capillary fringe is also unclear. It has been suggested that the flow stabilizes and fingers dissipate in that area. We performed two-dimensional experiments using a glass-bead porous medium in a chamber with an initially dry upper half and a capillary fringe in the lower half. Pressure heads in the induction zone, a finger, and the capillary fringe were monitored by microtensiometers while the wetting front was traced at regular intervals. The flow in the induction zone was governed by the fingers. The lateral flow direction could change as one finger gained dominance over another. When a finger entered the capillary fringe, the wetting front diverged strongly and the vertical pressure head gradient changed from opposing the flow to supporting it. This proved that fingers dissipated in the moist soil.

Effects of soil stability and water quality on erosion during a rainfall

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For many years the main issue of the soil erosion is decrease of land productivity. Recently environmental pollution by the eroded material from the agricultural land comes out. Focusing on clay colloid is important, since it determines behavior of the eroded soil particles and affects chemicals adsorb on and move with clay particles. This study aims to clarify the relation between clay colloid behavior and infiltration and soil loss during rainfall. Two soils from well-drained upland field and waterlogged upland field were used in this study. Critical coagulation concentrations (CCC) of clay suspension of the soils were 1.3 to 1.5 mmolc/L with $CaCl_2$ electrolyte solution and 70 to 100 mmolc/L with NaCl electrolyte solution. In the simulated rainfall experiment that has conducted in the Arid Dome, gypsum was spread prior to the rainfall to control electrolyte concentration of runoff. During the rainfall, Ca^{2+} concentration of runoff was estimated to be 15 to 30 mmolc/L, however coagulative effects of Ca^{2+} on infiltration into well-drained and waterlogged soils were observed only for the first 20min from the beginning of the rainfall. Difference between well-drained and waterlogged soils were observed for the same period.

B-1) Studies on Water and Salt Management on Woody Plants in Arid Areas

Estimation Temperature and Water Status on Soil Surface using Remote Sensing

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Estimation of ground surface information, especially temperature and water status, is an essential problem to investigate extensive evapotranspiration. The purpose of this study is to estimate soil surface temperature and water status using remote sensing.

Soil surface temperature is measured by thermotracer (TH-1101) and compared with soil temperature (depth from surface: 0, 5, 10, 15, 20, 50, 100mm) by thermocouple. Soil water status is measured spectroradiometer (Field Spec) and compared with soil water content (0, 5, 10, 15, 20, 30 mm) by weighing. The results show following facts. Thermotracer will measure soil temperature (0 and 5mm) regardless whether dry sand layer growth or not. Spectroradiometer will measure soil water content of surface. These examinations provide a remarkable problem the relation between angle of incidence and sensor. In the morning or evening, the angle of depression of incidence is large, both thermotracer and spectroradiometer are affected by the angle of sensor. This tendency become stronger at the elevation angle of sensor is small. The effect of the above problem is not very serious in the case of satellite remote sensing, but we must consider that at ground level remote sensing.

Evaluation of Biomass on the Aboveground Using Satellite Data

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Because of increasing of carbon dioxide concentration, several important problems in Earth's environment are occurred. This study was conducted to examine the possibility of estimating the biomass on the aboveground, especially standing tree volume using satellite data, as forest is well known of the absorbent of carbon dioxide. Spectral reflectance of the tree crown with several tree heights and ages were measured with handheld spectral radiometer at Takakuma Experimental Forest Station, Kagoshima University. Relationships between the spectral reflectance and tree variation (i.e., age and height) were analyzed. In the visible region (400-700nm), spectral reflectance were not changed with tree variations. On the other hand, spectral reflectance were differed with tree variations in the near infrared region (700-1050nm). These results show the possibility of estimating the standing tree volume with satellite data. Now we are developing the algorithm how to analyze the biomass, especially tree volume, with the result of spectral reflectance.

Environmental Assessment of Sakyu and Forest

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In order to classify the earth materials by using satellite image data, their individual spectral reflectance characteristics should be identified. This study aims to classify surface cover from Tottori sand dune and the adjoining forest by using TM data and field reflectance meter. Besides, the time-series analysis of the changes in the distribution of surface cover is also made based on the reflectance pattern.

Application of Remote Sensing and GIS Technology for Water Management/Land Use Change in Large Scale Irrigation Project in Arid Land

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In the arid land area of Southern part of Iran, there are developed large scale irrigation projects, Dez project in Khuzestan Province, Zahyande project in Isfahan Province, Drudzen project in Fars Province, whose areas are situated in downstream of large dam constructed in Zakros mountain range, and bigger than 100,000 ha. One of most serious problem is how to raise up efficiency of water use in irrigation, and second is protect of salinity problem. Application of remote sensing and GIS technology is preferable for water management in large irrigation project in arid land.

SPOT image observed in July 1987, and JERS OVN image observed in Aug. 1994 were used to analyse Dez irrigation project. It became useful for understanding land cover situations in project area. In future, linkage of satellite image and GIS data is more preferable.

B-2) Integrated Researches on Soil-Water-Plant Monitoring by Remote

Sensing

Numerical Study on Water and Salt Transport

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Salt accumulation process under soil-root system is numerically investigated. The method of characteristics and the implicit finite difference method are employed for solving convective-dispersive equation for salt transport and Richard's equation for water movement, respectively. Root water uptake under a saline condition is assumed to be described by the root contact model, which was developed by Herkelrath *et al*. (1977). The experimental data are also collected to examine the validity of the proposed numerical model. For a comparison, the program HYDRUS-2D, which is a finite element model for simulating two-dimensional water and solute movement in variably saturated media, will be applied to analyze the data. This issue will be addresses in future studies.

Undisturbed Measurement of Water and Salt Movement in the Large-Scale Soil Columns

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In order to prevent salinization problems in arid and semi-arid regions, it is essential to clarify the mechanisms of salt accumulation in soil. An experimental setup consisting of three large-scale soil columns was used to monitor dynamics of salt and water in a sand dune soil. The columns were 798mm in diameter and 1200mm in height which installed three kinds sensors on different depth. It was attached to a monitoring system for water flow and solute transport. The monitoring was carried out under a stable ground water level of 30cm in the Arid Land Dome for 90 days. Ground water with different levels of NaCl concentration (1000, 3000 and 5000mg/L) was used for the study. The results are as follows. Salt accumulation was remarkably shown at the depth of 3cm through the soil surface. Higher NaCl concentration of ground water caused faster and more salt accumulation and higher water content of the soil above the ground water table constantly. Wetness of surface soil was directly dependent on atmospheric humidity. This phenomenon was clear as salt accumulation progressed, especially at surface soil.

Effect of Zeolite Amendment on Water and Salt Control in Soil

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To observe the effect of zeolite amendment to control water and salt in soil, tracer tests were carried out using two large lysimeters. Sensors were set up at three positions of five depths (0.05, 0.15, 0.25, 0.45, and 0.65 m) for the measurement of water content, E.C., and pressure head. Tottori dune sand was packed into two large scale lysimeters. One of the lysimeters was packed by only Tottori dune sand and 5% (weight) of zeolite was amended to sand at the top 0.2 m layer of another lysimeter.

The effect of zeolite to increase the water retention capacity was very clear. Water content at the zeolite zone was high. While sand was packed into the lysimeters to keep constant condition (porosity, density and etc.), the spatial heterogeneity of water content and salt concentration on the horizontal section was clear.

Mechanism of Simultaneous Transfer of Water, Solute and Heat

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Evaporation experiments with and without 0.10 mol/kg NaCl solution were performed in two large columns to examine the effect of salt concentration on evaporation. The soil columns have 798 mm in diameter and 1200 mm in height, which was newly installed at the Arid Land Research Center of Tottori University. Water, solute and heat transports were monitored by three kinds of sensors: amplitude domain reflectometry sensors (ADR) for water content; four-electrode salinity sensors for bulk soil electrical conductivity; and thermocouples for heat. Microclimate such as solar radiation, net radiation and humidity were also measured to estimate evaporation flux. Each soil columns were once saturated with de-ionized water and NaCl solution. After gravitational drainage, evaporation experiments were started. The experiments were continued for about two months in a greenhouse on July and August to simulate the meteorological condition in arid land. Because of decreasing osmotic potential, the evaporation rate in high solute concentration was smaller than that in low salt concentration for first half of experimental period. On the contrary, decreasing matric potential caused smaller evaporation rate in low solute concentration for latter half. The effect of osmotic potential on evaporation was confirmed, which has been neglected by many researchers. Large columns with three kinds of sensors have successfully monitored simultaneous transfer of water, salt and heat.

Salt Movement in Soil with Salt Affected Ground Water

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In low land areas facing to sea water, the sea water intrudes into a ground water. Then, the salt in the ground water rises up to the top soil, after all, it causes soil salinization. In order to investigate the salt and soil water movement under the salt affected groundwater conditions, the salt movement monitoring system of ALRC was used. Tottori dune sand was packed in the system and a ground water with different salt concentration was given at a constant level, then the salt and the soil water movement followed by evaporation was monitored for 4 months. The ground water concentration was set at 1000, 3000 and 5000 ppm and the ground water depth was kept at 50 cm. Using smaller size columns, similar measurement was made under conditions at ground water depth 30 and 50 cm with 10000 ppm ground water salt concentration.

The experimental results showed; (1) salt accumulation was found in 1 to 1.5 cm layers from the soil surface, (2) the higher the salt concentration of the ground water was, the higher the water content and salt concentration of the surface soil increased, (3) the evaporation rate and the salt concentration of the surface soil under condition of the ground water depth of 30 cm was 3.4 times and 9 times greater than that of under the ground water depth of 50 cm, respectively.

Experimental results showed that both of high salt concentration of ground water and shallow ground water level greatly increase salt accumulation in the surface soil layer.

C) Free Subject on Arid Land Studies

Spectral Analyze of Arid Land Soil by Visible and Near IR Range

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Arid land soil in the world (Foreign arid land soil: 82 samples, Japanese dry land soil: 65 samples) was preserved in Arid Land Research Center, Tottori University. In this study, Distal images in arid land soil were measured by distal camera (Nikon, E900 COOLPIX900) in artificial climate room. Distal images were analyzed RGB by personal computer, foreign arid land soils were classified by distinctive analysis.

Numerical Simulation of the Flow Field over the Tottori Sand Dune and the Estimation of the Effect of the Vegetation on the Flow Field

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Three dimensional flow field over the complex surface of the Tottori sand dune are computed by means of the numerical simulation. Incompressible Navier-Stokes equation is solved to compute the flow field. Boundary fitted coordinate system is employed in order to get high resolution near the surface of the sand dune. Geographic data are obtained from the topographical map of the Tottori sand dune in 1981. By using the computer code developed in this study, three dimensional flow field up to 100m above the sea level is computed and the following results are obtained.
(1) The flow behind the second line of the dune in Tottori sand dune is not affected very much by the deviation of the wind direction when the wind comes from the northwest direction. On the other hand, it is greatly affected when the wind comes from the northeast direction.
(2) The calculations for the Reynolds number around 900 give the most adequate results among all calculations for the various Reynolds number.
(3) The correspondence between the flow field and the shape of the sand dune is made clear.
(4) The vegetation makes the flow slow down in the rear region of the vegetation.

Study on the Simulation of Sand Dunes Variation

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This study was carried out through field survey to make the mathematical model to simulate the variation of Tottori great sand dunes. The results got by this study can be divided into 2 piece largely.

First from the analysis using the data of sand surface variation measured every months in Tottori great sand dunes and the data of wind direction and velocity at Tottori airport, the strong wind from northeast carries sand to the sand dunes inside from the outside and cause to accumulate sand. And it is also shown that the strong wind from northwest and south causes sand dunes inside eroded and carry sand to the outside. Next wind field measurement was carried out for 3 times and the characteristic of each wind field is grasped for the northwest wind, northeast wind and south wind.

Fundamental Studies on the Relationship between Salinization and Evapotranspiration of Agricultural Lands in Arid Area

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The salinization and evapotranspiration are deeply related to each other. The aim of this study is in order to clarify the basic mechanism of saline of agricultural lands in the soil physical point of view.

At Shindori attached farm, Niigata University, we observed pressure head and water content during the growth period of paddy rice continuously using TDR and tensiometers. Water content and pressure head were respectively measured in plow layer, plowsole and subsoil in the temporality. Furthermore, the meteorological observation also carried out for the quantitative analysis of the evapotranspiration from mass balance in the soil.

Consequently, it became clear that amount of water uptake by root deeply depends upon photosynthesis. Since, upward water movement decreases in night time.

Micrometeorologocal Measurement of Methane Flux over a Rice Paddy Field

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Methane flux over a rice paddy field was measured using the micro-meteorological method, from around 10 a.m. and 12 p.m. four days during Aug.21 to Sept. 16, 1998. Methane flux, Fm, was calculated from the equation $Fm = H(\rho m1/\rho 1 - \rho m2/\rho 2)/[Cp(T1 - T2)]$: H refers to the sensible heat flux measured by the eddy correlation method, ρm the methane concentration, ρ the dry air density, Cp the specific heat for constant pressure, and Numbers 1 & 2 two measurement heights.

Measured methane fluxes considerably fluctuated with time, and those under the conditions of H>0 were much larger than those under the conditions of H<0. Measured fluxes also differed considerably every day. The mean methane flux on an average in all four days was 16.6mg/m^2/hr (-0.7to 43.6mg/m^2/hr). The mean flux under the conditions of H>0 was 47.5mg/m^2/hr (28.7 to 89.9mg/m^2/hr). And the mean flux under the conditions of H<0 was -2.0mg/m^2/hr (-18.4 to 11.5mg/m^2/hr).

Synthesis of Novel Abscisic Acid Analogues and Their Effect on Plant Growth

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Abscisic acid (ABA) and its glucosyl ester (ABAGE) strongly affect metabolism of plants; e.g. suppression of growth, closure of stomata, and inhibition of germination. It is noteworthy that contents of ABA and ABAGE in plants increase under drought stress. In order to elucidate the action mechanism of ABA, many analogues have been synthesized so far. Alkyl and glucosyl esters of ABA are representatives of the analogues and are hydrolyzed to have similar biological activities as ABA.

Thus, we planned to synthesize a series of ABA glycosyl esters having different types of glycan part. ABA esters, having appropriate stabilities against hydrolysis, will make it possible to control ABA concentration in plants. Thereby metabolism of plants can be regulated under stressed conditions. We have

been studying effective method to synthesize ABA glycosyl esters.

Study on Root Characteristics Relating to Stress Tolerance of Cereal Crops grown in Problem Soils with Aspects of Functional Morphology

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Increase in the root volume in deep soil layer often enlarges the crop ability of water- and nutrient-uptake, and improves the crop resistance to soil stress such as drought and nutrient deficiency. In this collaborative research, we discussed in morphological aspects how the vertical distribution of roots is determined. Upland and lowland rice cultivars (*Oryza sativa* L.) that form different root distribution in soil to one another were grown in upland field and plastic tubes (5cm in the diameter and 1m in the length with soil) to observe their roots. Combination of the researches on field-grown and tube-grown rice plants indicated that both the growth angle of roots and the final length of roots affect on the vertical distribution of whole root system. In addition, the final length of a root depends on both the growth rate and growing period of the root. Moreover, cultivars with thicker stem and slow plastchron usually had larger growth angle and growing period of roots. Establishment of a simulation model to describe the relationship of these shoot and root morphological characteristics is in progress.

Investigation of Gene in Relation to Root Development under Soil Drying

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Peal millet (*Pennisetum typhoideum* Rich.), is drought tolerant crop, which develops large root system under soil drying conditions. This root growth response might be genetically controlled, however, there are a few information on gene regulation of root development under water stress conditions. Objective of this research is to investigate specific protein, which is induced by gene under water stress conditions. Peal millet was grown under hydroponic culture. The plants were exposed to water stress by declining water level, as a rate of 2 cm d^{-1} downward the base of the shoot, during 10 days. Root system of upper and lower parts of the water level were taken. Protein of each part of root system were extracted and analyzed by two-dimensional electrophoresis. A comparison of two-dimensional protein patterns, from the upper part and the lower part of the root system, showed that water stress caused an increase of a 53 kDa protein with acidic pI and reductions of 23, 28, 36 and 38 kDa proteins with basic pI. This result suggested that these proteins might regulate the ability of root development under water stress conditions.

Screening Germination Stimulants for Parasitic Weeds

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Fusicoccanes including fusicoccines (FCs), cotylenins (CNs), ophiobolines and their synthetic analogs were examined for their effects on seed germination of important root parasitic weeds, witchweed [*Striga hermonthica* (De1.) Benth] and clover broomrape [*Orobanche minor* Smith]. Since FCs and CNs carrying different sugar moieties showed similar levels of stimulative activity and, in addition aglycones were more active than the corresponding parent compounds, aglycones appeared to contain the essential structure for stimulative activity. Furthermore, 9-deoxy-19- hydroxycotylenol was the most active among the compounds tested, indicating that the substituent on the 9-position is not needed for the activity. By contrast, the presence of a hydroxy group either on the 3- or 12-position seemed to be essential for the activity.

Fundamental Study on Natural Plant Growth Regulators for Enhancement of Crop Productivity in the Arid Land

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Striga hermonthica (Del.) Benth is an economically important root parasitic weed that causes considerable losses in yield of several cereal crops including sorghum, maize, millet and rice in the arid and semiarid tropics. Germination of a *Striga* seed requires an exogenous stimulant exuded by roots of host and some nonhost plants. Induction of seed germination in absence of host plants (suicidal germination) is one of the most effective methods for *Striga* control.

In an attempt to develop effective natural germination stimulants to enhance depletion of *Striga* seed reserves in soils, 500 fungal isolates were screened, *in vitro*, for metabolites with activity as *Striga* germination stimulants. As a result, a strain of *Cercospora kikuchii*, the pathogen causing soybean purple seed stain, purple blotch or purple speck was found to produce germination stimulants. These stimulants were purified from the culture filtrate of the fungus to afford two active fractions. Purification of one of these fractions by HPLC gave no active fractions, but the mixture of these HPLC fractions showed the activity. Further purification of the other fraction resulted in isolation of an active substance.

Comparative Study on Factor of Soil Concerning Biological Products on Desert

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Mineralization incubation test for semi biological organic waste contained deposit of dye works was

done in Ishikawa dune soil at 25 ℃ for 40 days with field water condition. In this condition change to nitrate was not almost observed.

Ecophysiological Studies on the Pine Wilt Disease Occurring in Coastal Dune

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The manner of expanding of the pine wilt disease in coastal dune was compared between two 20 x 20 m plots, with or without fertilizer treatment. Mycorrhizal development was examined between pine seedlings planted in the fertilized plot and ones in control plot. Mycorrhizal development observed was better in the latter than in the former, suggesting fertilizer applied suppressed the development of the mycorrhizae of pine trees growing there, and thereby reduce the resistance of such trees against the pine wilt disease. This maybe the one of the factors which determine the number of trees killed by pine wilt disease. Further studies are needed to ascertain this hypothesis and to follow the process of the pine wilt development in the same area on the coastal dune.

Ecophysiological Study on Drought Resistance of Tree Species in China

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The objective of this study was to examine the effects of acute water stress using measurements of chlorophyll a florescence of seven plants species growing in semi-arid region of China comparing with three plants species growing in Japan. Measurements of the chlorophyll fluorescence are efficient indicators of photochemical activity of reaction center. Some parameters were determined from chlorophyll a fluorescence using a pulse amplitude modulation fluorometer (Model MINI-PAM, Waltz).

Sample plants growing in small pots were stored in a growth chamber at controlled air temperature(25-30℃), humidity (30-40%) and light intensity for two weeks to experience various degrees of drought stress of soil water condition, indicated by pF value. Changes in chlorophyll a fluorescence with decreasing soil moisture content were monitored. Comparing these parameters, differences in sensitivity to soil drying were detected among sample plants. These differences could be interpreted as one of the drought resistance to maintain CO2 assimilation even in severe soil moisture condition.

Regional Development Policies and Farm-Corporation before the Islamic Revolution in Arid Land Area at Kor River Basin, Iran

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In March of 1997 ,1998 and 1999, I made a extensive field work of the ecology , such as weather conditions, the topography, soil, vegetation, water course and so on, around the southwestern part of the mountain district of Zagros in Iran. And also made inquiries of Pastoral farmers and nomads to collect basic materials of farming and livestock. This year, I focused on the irrigated farming area of Kor river basin which flows into the fertile and wide valley of Marvdasht, rises into the Zagros Mountains, and combined those micro findings which were observed in field surveys until now, and macro findings such as photographs from satellites and statistical materials. I would like to continue my research in greater detail to examine the relationship between the water utilization of irrigated farming, population growth, and the burden to the natural environment " artificial desertification " in this area.

In-situ Measurement of Soil Permeability

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A pressure infiltrometer method has been developed by Reynolds, W. D. and Elrick, D. E., Canada, to determine a field-saturated hydraulic conductivity based on a constant-head infiltration into a soil from a single ring. An applicability of the pressure infiltrometer method to sand soils is examined by field experiments in ALRC, Tottori University, and Faculty of Agriculture, Niigata University, and numerical calculations.

Values of the field-saturated hydraulic conductivity determined by the pressure infiltrometer method are about 27% in average larger than ones of soil cores 100cc in volume sampled from the test sites. The numerical calculations to simulate the constant-head infiltration from the single ring measured in the sand soil field shows that a soil parameter α_*, which describes a exponential function of an unsaturated hydraulic conductivity with a pressure head of soil, should be determined correctly in calculating the field-saturated hydraulic conductivity, as well as that a measurement depth of the pressure infiltrometer method in sand soil fields may be 15-25cm for a constant head of 10-20cm above the soil surface. Based on the results of the field measurements and the numerical calculations the soil parameter α_* of 0.06cm^{-1} mostly appropriate to the sand soils is recommended.

Analysis of Soil Water Movement by using the Generalized Model for Unsaturated Hydraulic Conductivity

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The unsaturated soil hydraulic properties are represented by the relationship between the volumetric water content and the soil capillary pressure head, and the hydraulic conductivity function. Some models

for water retention have been combined with pore scale models suggested by Burdine or Mualem for the purpose of deriving analytical expressions that can be used to predict the hydraulic conductivity. These combined water-retention-hydraulic-conductivity models have been widely used for the numerical modeling of soil water movement. However, recent studies suggested that predictions of the hydraulic conductivity based on the Burdine's and Mualem's models are inadequate for some soils. In this study, a combined soil-water-retention-hydraulic-conductivity model was developed for soils with lognormal pore-size distribution. The retention model contains two parameters: the capillary pressure head which is related to the median pore radius by the capillary pressure function, and the dimensionless parameter which is defined as the standard deviation of log-transformed soil pore radius. The general conductivity model has three additional parameters; two of which are related to the soil pore tortuosity, and the other parameter describes how to evaluate the effective pore radius. The conductivity model succeeded to reproduce observed unsaturated hydraulic conductivity values of Tottori sand.

Study of Water Management on 2 Varieties of Baker's Garlic Grown on Sand Dune Field

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Though sand dune fields are generally irrigated for cultivation, there are no established basis for determining the amount of water and the irrigation periods. In this study, the effect of irrigation, controlled by electric tensiometers, on the growth and characteristics of mineral absorption between two varieties of Baker's garlic was investigated. Conclusively, productivity was not improved, however the phosphorus concentration of root of two varieties increased by irrigation, suggesting that soil moisture may affects the characteristics of mineral absorption.

Salts Behavior in Soil

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For sustaining crop production in dryland agriculture, soluble salts must properly be managed in the field. To assess salt behavior in such environment, spatial and temporal distribution of water and salt in soil should be measured. We constructed a time domain reflectometry (TDR) system consisting of a TDR cable tester, a multiplexer, and probes for measuring both soil water content and electrical conductivity

representing salt concentration of soil water. This TDR system was controlled by a laptop computer and automated for acquiring data from multiple probes. This TDR system will be used for assessing water and salt contents in the root zone with variably changing groundwater depth by adjusting valves in tile drains.