

(2) Summary of Joint Research

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

Measurements and Simulation on the Profiles of Atmospheric Carbon Dioxide Concentration over the Vegetation under the Advective Condition

*Kyoko NAKAMOTO**, *Seiji HAYAKAWA***, *Makio KAMICHIKA**** and *Tamon TSUJI**

* United Department of Agricultural Science, Graduate School of Tottori University

** Faculty of Agriculture, Yamaguchi University

*** Arid Land Research Center, Tottori University

The objective of this study is to examine the effect of advection on the behavior of CO₂ over the vegetation. The measurements on atmospheric CO₂ concentration were conducted in the sorghum field in Arid Land Research Center, Tottori University when the land and sea breezes were dominant. The numerical simulation of atmospheric CO₂ concentration over the canopy surface under the advective condition was also examined, solving the nonlinear two-dimensional steady-state equations in the surface boundary layer.

Both the diurnal changes and profiles of CO₂ concentration over the sorghum field were affected largely by the respiration and photosynthesis of plants. The largest peak of CO₂ concentration was observed during the transition of land and sea breezes. For both daytime and night, observed profiles were very much like theoretical profiles obtained from the evaluation taking the stability of each layer into account. From both simulation and observation, we could find that the CO₂ profiles would be affected by the advection from the surroundings and CO₂ concentration at 0.8m would be higher by about 1.5ppm at the downwind point than at the upwind point 20m far from the upwind.

Relationship between Evapotranspiration and Penman's Potential Evapotranspiration in the Greenhouse

*Takesi MIURA**, *Noboru MORITA**, *Kyoichi OTSUKI*** and *Makio KAMICHIKA***

* Faculty of Environmental Science and Technology, Okayama University

** Arid Land Research Center, Tottori University

Evapotranspiration ET and Potential evapotranspiration PET estimated by Penman's method in the greenhouse, where watermelons were cultivated, was investigated. The greenhouse, covered by vinyl sheet, was 5.4m width, 17m length and 2.9m height. There were two ridges of 2.3m width and 10cm height in the greenhouse, which were covered by mulch on the soil surface. The watermelons were planted on the ridges and covered by vinyl tunnel. Water was irrigated through the porous tubes under the mulch. ET is calculated by water budget of the soil, and PET is calculated using the meteorological data in the greenhouse. The results show that crop coefficient, the ratio of ET to PET, was 0.23 in the early stage, 0.84 when the leaves covered most of the soil surface, then became 0.31 in the latest stage.

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

*Masahiro YOSHIHARA**, *Nobuhiro MATSUOKA**, *Son GU***, *Kyoichi OTSUKI*** and *Makio KAMICHIKA ***

* Faculty of Horticulture, Chiba University

** Arid Land Research Center, Tottori University

Soil moisture of Tottori sand dune is estimated using the routine meteorological data observed in the meteorological station of Arid land Research Center, Tottori University. Soil moisture estimation model of Nakayama (1991), based on the water budget using the modified Davies and Allen model (1973) to estimate evapotranspiration, is used for the calculation. The estimated soil moistures in the period of July-August, 1995 are compared with the measured ones of 0, 1, 2, 3, 4, 5 and 10cm depth. The results show that estimation values coincide with the measured ones within 2mm. The results also indicate that the soil moisture should be measured up to 40cm depth and the dry surface layer, which prevent evaporation, should be considered in the model.

A-2) Hydraulic Design and Water Management of Microirrigation

Development of Chemical Injection in Micro Irrigation System using the Bend Pipe

*Soichi NISHIYAMA** and *Tomohisa YANO***

*Faculty of Agriculture, Yamaguchi University

**Arid Land Research Center, Tottori University

In this paper, the characteristic of bypass flow across 90 degree curve pipe were investigated. The relation of between main pipe flow rate and bypass route flow rate is clarified. The estimation method of bypass flow rate is proposed. Above study results help us to design the flow meter and chemical injection system in irrigation facility using the bend pipe.

Numerical Study on Water and Salt Transport

*Kazuro MOMII** and *Tomohisa YANO***

*Faculty of Agriculture, Kagoshima University

**Arid Land Research Center, Tottori University

A simulation model with cation-exchange reactions was developed and applied to solute-transport analysis in a saturated soil column. Chemical reaction terms in the convective-dispersive equation were estimated by the Levenberg-Marquardt non-linear least-squares regression technique to satisfy physical and chemical processes simultaneously. The reliability of the model was verified with the breakthrough

curves of Ca, Mg, Na, K and Cl after pulse-type injection of KCl solution into steady, saturated water flow.

The experimental results revealed that the selectivity coefficients for Ca-Na and Ca-Mg exchange could be kept constant, while those for Ca-K exchange increased with the equivalent fraction of K in the solid phase. The spatial distribution of the chemical reaction terms are illustrated to evaluate the effect of cation exchange reactions on transport behavior. Although further investigation on the applicability of the model to other chemical reactions in soils may be needed, the model will be useful for water quality assessment in the subsurface environment.

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

Root System Structure in Relation to Water Collection and Conductance in Crop Plants

*Akira YAMAUCHI**, *Shinobu INANAGA*** and *Yukihiro SUGIMOTO***

*School of Agricultural Sciences, Nagoya University

**Arid Land Research Center, Tottori University

We examined cell wall lignification in hypodermis, endodermis and xylem vessel development in roots which are related to hydraulic conductance, and that in lateral roots which mainly regulate water collection for cowpea and maize grown under well-watered and drought (no irrigation) conditions. Plants were grown in soil-filled root boxes for 17 days. Area of lignified cell wall was quantified using photo images produced with phloroglucinol-HCl reaction and epifluorescence microscopy, which were then subjected to computer image analysis. Drought substantially promoted such lignification in xylem tissue on basal part of taproot for cowpea and in hypodermis, endodermis and xylem in stele of almost all parts of the seminal root for maize. Drought inhibited xylem vessel development for both species. In cowpea, the ratio of xylem vessel area to lateral root length decreased acropetally under both water regimes, indicating larger hydraulic conductivity for more basal part of taproot, which is reasonable. In contrast, in maize, due to the promoted development of lateral roots, such ratio greatly reduced all along the seminal root especially under drought. These facts indicate that water conducting and collecting parts in a root system show different developmental and probably functional plasticity, which depends on growth conditions and species.

Respiration Cost in Rice Increases by Root Development under Low Soil Moisture Conditions

*Tohru KOBATA**, *Takayuki ASAKI** and *Shinobu INANAGA***

*Faculty of Life and Environmental Science, Shimane University

**Arid Land Research Center, Tottori University

High capacity of root development under desiccated soil conditions contributes increments of water absorption, so that dry matter production can be maintained, but respiratory loss of assimilate from the

roots may increase. Our objectives were to establish whether root developments of rice under low soil water conditions accelerates respiratory loss to clear the cultivar differences. Two cultivars of different drought resistance, Nipponbare and Senshou, were used and planted in pipes of a diameter 8.3 cm and a length 100 cm. Plants were well irrigated for 27 days after sowing and water table was changed in 45, 20 and 10 cm from the bottom for 20 days. At 3 days after, ^{13}C was fed for 4 h and translocation and loss of the carbon during 17 days were estimated. When water table was lower, dry matter and carbon gain in plants were suppressed but partition of carbon into root system increased. The ratio of respiratory loss to carbon gain of whole plant increased. Cultivar differences in the respiration rate was not clear. We concluded that acceleration of carbon partition into roots under low soil moisture conditions resulted in increases of respiratory cost regardless for cultivar.

Study on Root Characteristics Relating to Stress Tolerance of Cereal Crops with Aspects of Functional Morphology

*Jun ABE**, *Junko YAMAGISHI**, *Shinobu INANAGA*** and *Yukihiro SUGIMOTO***

*Graduate School of Agricultural and Life Sciences, University of Tokyo

**Arid Land Research Center, Tottori University

It is supposed that root endodermis play rolls of barrier for radial water movement in plant roots. Cell wall thickness of root endodermis was measured by a scanning electron microscope (SEM). Seeds of a japonica-type lowland rice cultivar (Koshihikari) and two tropical japonica-type upland rice cultivars (IRAT109 and Moroberekan) were planted in plastic tubes (5 cm in the diameter and 50 cm in the length) filled with fertilized soil. While roots of the rice seedlings were washed out of the soil 2 weeks after planting and kept in 70% alcohol solution. Cross sections of seminal roots at positions of 2 cm, 5 cm, and 20 cm from the root tip were prepared by hand-section method. Photos of the cross sections with x 1,800 – x 3,500 magnifications were taken by the SEM (Nippondenshi JSM-5800) in ALRC. The thickness of inner-side (stele side) and outer-side (cortex side) walls of endodermis was measured on the photos. Cell walls of endodermis thickened basipetally along the root axis in particular inner-side walls in all the three cultivars. The cell size of endodermis was larger in the two upland rice cultivars than in the lowland rice cultivar, and so the wall thickness. The varietal difference in the cell-wall thickness of endodermis may be related to the drought tolerance of the three cultivars, because the secondary thickening of cell walls involves deposition of suberin and lignin that may prevent from water-leakage of roots.

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

Effects of Salt Water Irrigation on Growth of Easter Lily

*Hiroshi OKUBO**, *Mizue IDE** and *Masao TOYAMA***

*Faculty of Agriculture, Kyushu University

**Arid Land Research Center, Tottori University

Effects of salt concentration in irrigation water on growth of Easter lily (*Lilium longiflorum* Thunb.) were investigated. The bulbs of the plant, 18.8 cm in circumference, were planted in sand in plastic pots (23 cm in diameter) on 24 October 1996 and grown in a greenhouse. Tap water was applied until the 18 February of the next year, and then 500 ml of 0, 500, 1000, 5000, 10000 or 15000 mg l⁻¹ salt water was applied per pot when watering. Eight plants were used for each treatment.

Up to the concentration of 1000 mg l⁻¹ either the days to flowering or the plant height were almost the same among the treatment. Plant height was shortened and flowering was delayed at the concentration of 5000 mg l⁻¹ or higher. All the plants, however, still survived even in 15000 mg l⁻¹ salt water although the plants showed dwarf.

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

Studies on Salt Tolerance of Tree Species

*Tsuneo NAKASUGA** and *Shigenobu TAMAI***

*Faculty of Agriculture, University of the Ryukyus

**Arid Land Research Center, Tottori University

The behavior for the salinity was studied using a Okinawan mangrove species, *Kandelia candel* in a greenhouse at University of the Ryukyus, Okinawa. The viviparous seedlings of *K.candel* were controlled under three salt conditions, 0 %, 1.8 % and 3.6 % of the salt water. After four months, growth of the seedlings was the best in 1.8 % salt concentration of the soil water. The decreasing rate of photosynthesis at before and after the acute treatment of high concentration of salt water was increased with increases in salt concentration of the soil water. From the patterns of absorption and diffusion of N and K in each part of the seedling, it estimated that medium root which has spongy parenchyma has an important role for the salt tolerance of the seedlings.

Pre-planting with *Salix psammophila* on Coastal Sand Dunes – Direct Planting of Cuttings

*Masazo TOKUOKA** and *Shigenobu TAMAI***

*Faculty of Agriculture, Kyoto Prefectural University

**Arid Land Research Center, Tottori University

Two experiments involving planting of *Salix psammophila* cuttings at different altitudes were conducted on the Hamasaka sand dunes in Tottori. (1): We studied the effects of the parts from which the cuttings were taken and planting depth. The new shoot length of cuttings taken from the basal portion exceeded that of cuttings taken from the upper portion. The number of new shoots increased with decreasing planting depth, while the maximum new shoot length increased with increasing planting depth. (2): We planted the cuttings in two ways: planting by the ordinary method, bending the cuttings and planting both ends. The number of new shoots for style tended to be greater than that for style . In contrast, the maximum new shoot length for style tended to exceed that for style . In both

experiments, the relationship between the number of new shoots and the maximum new shoot length was similar. By late summer, all the cuttings had died except for some of those planted in stands of *Robinia pseudo-acacia*. On the coastal sand dunes of western Japan, the atmospheric and the ground temperatures in mid-summer are higher than those in sandy districts of continental China, and the groundwater level is low. It is suggested that it is difficult to grow *Salix psammophila* cuttings on coastal sand dunes because of the harsh conditions prevailing there.

Growth, Phenology, and Drought Tolerance of *Acacia* Species Distributed in Semi-arid Area

*Fukuju YAMAMOTO**, *Norikazu YAMANAKA*** and *Shigenobu TAMAI***

*Faculty of Agriculture, Tottori University

**Arid Land Research Center, Tottori University

Growth and phenology of *Acacia albida*, *A. nilotica* and *A. raddiana* seedlings were studied. The seeds of those species derived from Sudan were sown in vermiculite in July, 1996 in the greenhouse of the Arid Land Research Center. After germination, 18 seedlings were selected and separated into three groups: 1) six unstressed plants, 2) six moderately-stressed plants (pF 2.5), and 3) six severely-stressed plants (pF 3.2). The six seedlings of each group were transplanted in vermiculite in a 60 x 60 x 80 cm plastic pot. The water content in each pot was regulated by the weighing of water loss from pots with a platform scale every day since August, 1996. The growth rate and phenology of the seedlings were determined for 17 months from July 18, 1996 until December 23, 1997. The rate of height and diameter growth in *Acacia nilotica* and *A. raddiana* seedlings significantly decreased under moderate or severe drought stress, whereas the growth of *A. albida* was maintained under the stressed condition.

The anti-oxidation ability as an index of drought tolerance was determined in potted, 1-year-old *Acacia albida*, *A. nilotica*, *A. raddiana* and *A. tortilis* seedlings. The anti-oxidation ability of *Acacia* species was estimated by the determination of suppression rate of chlorophyll degradation by adding the juice of *Acacia* leaves with a spectrophotometer. The thylakoid membrane of spinach chlorophyll was used as the material of this assay. The anti-oxidation ability of *A. nilotica* was higher than that of other species. This ability increased as the increase of drought stress.

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

On the Slope Protection from Soil Erosion in Shirasu using a Non-woven Fabric

*Kenzo HOSOYAMADA** and *Tahei YAMAMOTO***

*Faculty of Agriculture, Miyazaki University

**Arid Land Research Center, Tottori University

This study began in the spring, 1993 and the observations have been continued and following results were obtained.

1. Vegetations of Shirasu slope covered by non-woven fabric were continuously vigorous and the values

of biomass C,N, and Total C,N of Shirasu soil sampled from the slopes covered by non-woven fabric kept also high level.

2. Non-woven fabric filter method was effective to protect the soil erosion of Shirasu soil also at early period of construction.
3. To raise the reliability of this method in case of Shirasu soil, combining of seeds, volume of soil improving materials and fertilizers are also important problems.

Preferential Flows and Solutes Transport in Sandy Soils

*Hiroyuki CHO**, *Gerrit H. de ROOIJ**, *Tahei YAMAMOTO*** and *Mitsuhiro INOUE***

*Faculty of Agriculture, Saga University

**Arid Land Research Center, Tottori University

Preferential flow paths (fingers) can form in a conductive topsoil that is very dry or hydrophobic. At larger depths the soil is often wettable and less dry. Some researchers found that fingers persist in moist soils and derived an expression to calculate the finger size in non-dry soils. Others state that fingers dissipate in wet soils, owing to the fact that in moist soils there is no water entry pressure head that needs to be exceeded. Whether fingers widen or dissipate in response to an increased soil water content strongly affects the time it takes solutes to reach the groundwater. We experimentally studied fingers in two-dimensional fine-over-coarse profiles of glass bead porous media. The top of the coarse layer was air-dry. The bottom was prewetted and drained to approximate a natural moisture profile in a soil having a shallow water table and subject to a high evapotranspiration rate. Early results indicate fingers dissipate in a very wet subsoil.

The Experimental Study on the Rill Formation Process on a Bare Slope - Plane and Cross-sectional Patterns of Rills-

*Mitsuo FUKADA**, *Tahei YAMAMOTO*** and *Mitsuhiro INOUE***

*Division of Eco-Environmental Science, Department of Biological Science,
Faculty of Agriculture, Yamaguchi University

**Arid Land Research Center, Tottori University

As the sediment runoff by rill erosion is considerably larger than that by surface erosion or sheet erosion, it is important to reveal the development process of rill erosion. In this study, the authors have firstly described the characteristics of plane and sectional patterns of rills, sediment and water discharge with the passage of time based on a series of experiments applying the artificial rainfall on a slope. Secondly, to express numerically the degree of complication of the plane patterns of rills, the geometrical concepts of the Fractal dimension and the Spectrum have been applied. The time variations of these values have been compared with the experimental data of sediment and water discharge.

The findings of the observations are :

- 1) The plane and the cross sectional patterns of rills change rapidly during the first few ten minutes and thereafter the rate of changes becomes slow.

- 2) The sediment discharge increases rapidly during the first few ten minutes, but decreases after showing a maximum value at about 30-40 minutes after starting the application of artificial rainfall.
- 3) The plane and the cross sectional patterns manifests complex phenomena and the water-course is unstable during the first few minutes of the generation of rill on the slope and after few ten minutes, the position of water-course becomes stable and the erosion proceeds in the vertical direction.

Analyses of the plane patterns of rills by the Fractal dimension shows a curve of fluctuation (increasement) during the first few minutes and thereafter change with time. Such a behavior is very similar to the outflow of water and the discharge of sediment from a slope.

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

*Yuji TAKESHITA**, *Mitsuhiro INOUE*** and *Tahei YAMAMOTO***

* Faculty of Environmental Science and Technology, Okayama University

** Arid Land Research Center, Tottori University

Knowledge of the unsaturated soil hydraulic properties is essential requirement for prediction of seepage flow and contaminant transport through the vadose zone. The unsaturated soil hydraulic properties consist of the hydraulic conductivity as a function of pressure head and the soil water retention curve. Traditionally, steady state experiments have been used to estimate these properties. Recently, the transient methods are becoming more popular. Transient experimental methods are inherently faster, and because more powerful computers and seepage flow simulation are now available, the estimation of the hydraulic properties using inverse methods has become more useful.

In this research, a new parameter estimation methodology of determining unsaturated soil hydraulic properties from laboratory transient outflow experiments was investigated. In this method the unsaturated soil hydraulic properties are assumed to be represented by van Genuchten's closed-form expressions. Unknown parameters of this model are estimated by Genetic algorithms (GA) incorporating finite element solution of Richards equation. GA is one of the increasingly popular global optimization methods. Measured soil water pressure and cumulative outflow data as a function of time were used to evaluate the objective function in our GA-based method.

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. It has the possibility of identifying the optimal saturated hydraulic conductivity and unsaturated soil hydraulic properties in van Genuchten's equations simultaneously. The utility of the GA-based parameter estimation procedure is demonstrated using experimental data for Japanese decomposed granite soil. An excellent agreement between optimized and independently measured soil water retention data and saturated hydraulic conductivity were found.

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

Water Dynamics in Citrus Tree

*Tetsuo SAKURATANI**, *Hirokazu HIGUCHI**, *Tomohisa YANO*** and *Shigemitsu TAKAGI***

* Graduate School of Agriculture, Kyoto University

** Arid Land Research Center, Tottori University

The objective of this study was to quantify the accuracy of transpiration (T) estimated using stem heat balance, porometry and Penman-Monteith methods. Measurements were made on three citrus trees raised in three lysimeters in a greenhouse on 17-18 September, 1997. Gravimetric measurements of evapotranspiration (ET) in the lysimeter were used as the standard for comparison. Differences between lysimeter ET and stem heat balance T were much less than differences between either porometer or Penman-Monteith T and stem heat balance T . It was confirmed that heat balance sensors provide continuous, non-destructive and direct measurements of transpiration and are a valuable tool for study on water dynamics in citrus trees.

Studies on Water Requirement of Several Fruit Trees

*Kuniaki TAKAHASHI**, *Noboru NAKATA** and *Tomohisa YANO***

* Faculty of Agriculture, Tottori University

** Arid Land Research Center, Tottori University

Water requirement of fruit trees is very important factor needed to clarify in agriculture in arid lands where the efficient use of water is necessary. In this study, the nursery stocks of 'Nijisseiki' pears, 'Huiji' apples, 'Kyoho' grapes, and 'Hakuho' peaches planted in the vinyl greenhouse were used for measuring water requirement. Evapotranspiration from a tree was calculated by subtracting drainage amount from irrigation during the growth period. Each pot was covered with polyethylene films to prevent surface evaporation. The net production was achieved using the difference between the total dry matter of the tree just before leaf fall and that of dry weight of nursery stock. It was found that the water requirement during the growth period was 310 ml for 'Nijisseiki' pears, 342 ml for 'Huiji' apples, 374 ml for 'Kyoho' grapes, and 662 ml for 'Hakuho' peaches

Ecophysiological Study of Drought Damage on Japanese Trees

*Tatsuaki KOBAYASHI**, *Norikazu YAMANAKA*** and *Shigenobu TAMAI***

*Faculty of Horticulture, Chiba University

**Arid Land Research Center, Tottori University

Recently, serious damages of Japanese trees caused by summer drought are often reported. For the coming global changes, the prediction of drought damage has become important even in humid temperate

areas.

1. Effects on photosynthetic processes

The responses to heat and water stress were studied for *Stewartia pseudocamellia* (Sp), *Stewartia monadelphica* (Sm), *Cornus florida* (Cf), *Liriodendron tulipifera* (Lt) and *Quercus serrata* (Qs). Carbo-oxylation efficiency and photon yield of Sp decreased on 40 . Stomatal conductance of Cf and Lt was suppressed and recovered after treatment. The effect was seldom observed on Qs. Due to complex effect of heat and water stress, the photosynthetic processes of Sm and Cf were inhibited under the more mild condition than single stress.

2. Mathematical model on drought injury

The model was composed of the sub-models of evapo-transpiration, water uptake, changes of soil moisture and dehydration. On the assumption of the physiological parameters of *Populus alba*, heat injury was caused on the higher air temperature than 38 . If LAI of stand of *Populus alba* is 6 and available soil thickness is 50cm, drought damage was caused after 2weeks of rainless period.

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

Analysis of Surface Temperature on Kagoshima Prefecture - Considering Surface Emissivity on Landsat-5/TM Data -

*Etsuji ISHIGURO**, *Yutaka HORAKU***, *Tomohiro TABATA**, *Ryuichi YONEMURA***, *Muneharu SATO**,
*Hiroyuki KIKUKAWA****, *Makio KAMICHIKA*****, *Kyoichi OTSUKI***** and *Yasushi ABE*****

* Faculty of Agriculture, Kagoshima University

** PASCO CO. Ltd.

*** Faculty of Fisheries, Kagoshima University

**** Arid Land Research Center Tottori University

Greenhouse effect was recognized as one of the most important problems to be solved among the environmental issues. This study focuses to obtain basic data of global warming and also to establish a method of evaluating ground surface temperature using satellite data. As thermal infrared data of Landsat-5/TM have a better spatial resolution than the data of NOAA/AVHRR and GMS, they have been employed to estimate surface temperatures in many cases. However, it has been pointed out that surface temperature observed by Landsat-5/TM is different from the temperature observed on a corresponding ground spot. The correction method of band-6 in Landsat-5/TM using the relationship between Landsat-5/TM and NOAA/AVHRR data was proposed by Inanaga et al. And AMedAS and GMS data were compared by Horiguchi et al. However, these results were based on the temperature of a Black body. This study, therefore, proposes a new method for estimating surface temperature using Landsat-5/TM adapting spectral emissivity on the several target areas. This result was compared with other conventional methods.

The Basic Study for Identifying Vegetation Structure and Physiology using Remote Sensing

*Yoshiaki HONDA**, *Yasusi KAJIWARA**, *Chiaki OKANO** and *Kyoichi OTSUKI***

* The Center of Environmental Remote Sensing, Chiba University

** Arid Land Research Center Tottori University

In order to contribute the study of Earth environment change detection and prediction, especially related vegetation, it is required to establish the method for vegetation environment monitoring and the models for prediction. In the semi-arid area, the sparse cover vegetation has high sensitivity for environmental changing. It can be said that the area is suitable for collecting basic information which has capability to establish basic models. We have a test site in Mongolian grassland for collecting some parameters such as ground surface spectral information, biomass of corresponding area, 3D structure of the grass and so on. These parameters are basic information for developing the model which estimate biomass from satellite data. However, these samples can be collected in limited season and it is difficult to collect the physiology parameter in test site.

In this study, we've tried to identifying the vegetation structure and physiology data. 3D structure of the grass was measure by using 3Dlaser scanner. The data were analyzed for detecting apparent grass coverage. The vegetation coverage has closed relation to the standing biomass. Finally, we were able to clarify the standard method for connecting the apparent vegetation coverage and the standing biomass. This results is the important information for satellite data analysis for estimating the biomass.

Land Cover Classification of Satellite Images in Tottori Low Flatland

*Hisashi FUJIMURA**, *Makio KAMICHIKA*** and *Kyoichi OTSUKI***

* Faculty of Engineering, Tottori University

** Arid Land Research Center Tottori University

In order to classify the earth surface materials by using Satellite image data, their individual spectral reflectance characteristics should be identified. This study aims to obtain the spectral reflectance curves of individual surface materials, Tottori sand dune, water area, green area, artificiality area, naked land area, coastal field area, rice field area in Tottori city. Every surface material was categorized by means of the decision tree classification method and neural network.

Application of Satellite Image Data to Land Use Change, Water Management in Large Scale Water Use System in Arid Area

*Seiji TORII** and *Tahei YAMAMOTO***

*Faculty of Agriculture, Kyoto University

**Arid Land Research Center, Tottori University

In arid lands in the southern part of Iran, a large-scale water use system extending over 100,000 ha in area has been developed. Problems here concern, first of all, distribution of water. Utilization of satellite images is the best way to observe the state of irrigation in a large-scale land cover. The study aims at grasping the actual state of water management by observing the project areas in time series. In a long-term view extending over several decades, such a project can show upgrading of land use in response to social circumstances. In this aspect, we are also considering analysis of the state in which a large-scale irrigation project results in social development.

C) Free Subject on Arid Land Studies

Three dimensional numerical simulation of the flow field over Tottori sand dune

*Tetsuya KAWAMURA**, *Yuki MOROHOSHI** and *Makio KAMICHIKA***

* Graduate school of humanities and sciences, Ochanomizu University

** Arid Land Research Center, Tottori University

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. The numerical method used in this study is the MAC method which is the standard method for the calculation of the three dimensional 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. As a result, detailed structure of the flow field is obtained and the effect of the wind direction on the flow field is estimated. The result suggest the correspondence between the flow field and the shape of the sand dune is made clear. The effect of the vegetation on the flow field is also investigated. This effect is simply incorporated into the equation of the motion by adding the friction term. As is expected, the vegetation makes the flow slow down in the region of the vegetation.

Ethnopedological and Ecotechnological Study for Sustainable Agricultural Development in a Sahelian Watershed, Niger

*Keiichi HAYASHI**, *Toshiyuki WAKATSUKI***, *Kyoichi OTSUKI****

*United Graduate school of Agricultural Sciences, Tottori University

**Faculty of Life and Environmental Sciences, Shimane University

***Arid Land Research Center, Tottori University

The job of development cooperation is not just to help secure food supply, but also to increasingly conserve production resource. Sustainable agricultural development in general and the sustainable management of agricultural soil in particular are keys (Steigner K.G., 1996). However, most activities going on especially in semi-arid developing countries, are still far from this concept because supplying

food and conserving soil regard as a separate ideas. To achieve supply and conservation, it is necessary to adapt a technique based on the idea derived from the farmers' life experiences and not a broader perspective.

The objective of this research is to collect agricultural, pedological and ethnological information from a specific region and extract available ideas to develop the agricultural system in semi-arid regions. To achieve this objective, indigenous knowledge in a bench mark watershed were collected, evaluated, and compared to the laboratory data of soil samples. Bench mark site (B.M.S.) for this research was chosen from an inland watershed area near Matankari, 300 km east of Niamey, the capital of the Republic of Niger, West Africa. The common language in the B.M.S. is Hausa.

According to the indigenous information taken from the B.M.S., the farmers have specific names for each type of soil depending on their own evaluation of its color and fertility. For instance, there are three types of soils for cultivation of millet and cowpea. These are *baka-kassa*, *ja-kassa* and *phara-kassa*. *Bakka* means black, *ja* is red and *phara* is white. With respect to fertility content, *baka* has high fertility, *ja* has low and *phara* has very low fertility. *Kassa* means soil. Infertile soil called *le'sso* is also present in other areas. This soil was degraded by over cultivation. In other areas, there is a type of soil called *baringo*. This means that there is more clay and is fertile for cultivation. The farmers prefer this soil for sorghum and ground nut cultivation. Soil in wadi (temporal stream) is called *hori-rairay*. *Hori* also means white and *rairay* means not appropriate for crop cultivation. Soil in bas-fond (temporal swamp) is called *fakon-kounkou*. *Fakon* means hard and *kounkou* especially means clay soil. This soil is particularly used for small size irrigation or local rice (*Olyza graberimma*) cultivation.

The result of the data analysis of the soil samples corresponds well to the evaluation made by the farmers. In terms of particle size distribution, for instance, *fakon-kounkou* is hard clay. This clay from the upper part is carried by runoff water. *Baringo* is sandy clay loam. In arable land, the clay content is slightly higher in *baka-kassa* and lower in *phara-kassa*. With respect to biological property, each soil being used for cultivation has relatively higher content of organic matter than uncultivated soil. The chemical property reflects well with the result of the particle size distribution.

As a result, it is clear that indigenous information derived from the experiences of the farmers give us important information in B.M.S. Therefore, it is necessary to adapt this kind of indigenous knowledge to attain the sustainable agricultural system, not only in terms of food supply but also soil conservation.

Study on the Change of Sand Dunes due to the Removal of Sand-Protection Trees

Hiroshi YAJIMA and Makio KAMICHIKA***

* Faculty of Engineering, Tottori University

** Arid Land Research Center, Tottori University

At Tottori great sand Dunes, the sand-protection trees were partly removed to improve the sand movement. In this study, the change of the sand dunes after the removal of trees was examined using aerial photos and site investigation data.

Three main results got by this study were as follows:

- (1) From the analysis of aerial photos taken in three different year, it is shown that Dainisakyuretsu moves to the south-west direction and the ridge of it is getting longer after the removal of sand-protection trees.
- (2) The variations of sand surface are measured at more than 60 points every months in site

investigations for more than five years. The analysis of these data shows that the quantity of sand movement is increasing year by year. And when the data of observed points are divided for three areas (inland area, seaside area and near sand-protection trees area), it is found that the quantity of sand movement is biggest in seaside area and is smallest in the near sand-protection trees area.

- (3) By the regression analysis using meteorological data and the data of sand movement, it is shown that the strong wind activates the sand movement and precipitation and snow prevent the sand from moving.

Spectral Reflectance of Soybean Leaves Affected by Water and Salt Stresses

*Yasuhide FUJIYAMA**, *Tamaki KAWAMOTO***, *Kyoichi OTSUKI*** and *Makio KAMICHIKA***

* Faculty of Agriculture, Tottori University

** Arid Land Research Center, Tottori University

Spectral reflectance of soybean leaves affected by water and salt stresses was measured and discussed its features. After 45 days of growth under hydroponic culture, stress treatments; water stress, salt stress and control, were started. In the water stress plot, water was completely cut off. In the salt stress plots, two plots of which the concentration of NaCl were 3,000ppm and 10,000ppm were set. Spectral reflectance was measured above independent leaf and the canopy using spectrometer. It is found that the spectral reflectance shows the specific features depend on the type and intensity of the stresses and the measured parts. The results also show that the water contents and chlorophyll concentrations of the leaves can be calculated by the average spectral reflectance of 1445-1455nm and 660-670nm.

Measurement of Water Vapor Flux Using the Micrometeorological Methods

*Hikomichi ODANI** and *Tomohisa YANO***

* School of Environmental Science, University of Shiga Prefecture

** Arid Land Research Center, Tottori University

Effects of wake turbulence generated by the interaction between the turbulence and the rice canopy were examined in terms of the sensible heat fluxes measured with the energy balance Bowen ratio method and the eddy correlation method. The dry and wet bulb temperatures were measured at five heights over a rice field (crop height was 0.90-0.95m), and the sensible heat fluxes were measured at two heights with the eddy correlation method. The dry and wet bulb temperatures at the lowest level were measured at the height of 0.98m near the top of the rice canopy.

The two sensible heat fluxes measured with the eddy correlation method agreed satisfactorily. The dry and wet bulb temperatures at higher four heights were fitted to respective empirical equations, and it was found that the dry and wet bulb temperatures measured at the lowest level were different from those calculated from each equation. The sensible heat fluxes, which were calculated from temperatures at higher two heights among four heights using the energy balance Bowen ratio method, agreed satisfactorily with those measured using the eddy correlation method. However, the heat fluxes calculated from temperatures at lower two heights did not agree satisfactorily. From these results, the existence of

wake effects was inferred, and it was considered that flux measurements should be made over a height 1.5 times the height of rice plant.

Productivity of Wheat Culture in Arid Region of China

I. Observation of Wheat Plant Grown in the Field

*Tadashi TAKAHASHI**, *Akihiro ISODA***, *Shinobu INANAGA**** and
*Yukihiro SUGIMOTO****

* Faculty of Agriculture, Yamaguchi University

** Faculty of Horticulture, Chiba University

*** Arid Land Research Center, Tottori University

Arid region of Xingjiang in China is known for high yielding of wheat. Authors visited there on late July 1997 to observe the wheat plant grown in this area and investigate the morphological differences from one in temperate area Japan. At that time, although most of wheat had been already harvested at low land, authors could observe upland wheat at the foot of mountains. Each ear had many spikelets, additionally many grains per each spikelet, of wheat in this area, while there seemed to be not so much ears in unit area. Especially, authors had often found six grains per spikelet in Xingjian wheat. Disappearance of snow in spring is earlier there than snowing area in Japan, for example, Hokkaido. Thus, the formation period must be lontherned by this, there. This may be the one of reasons for the large sink capacity of an ear. In the next, physiological investigation should be necessary to evaluate the agricultural value for this potential sink capacity of an ear.

Time Course of Bleeding Rate with Reference to Root System Development in Field Grown Maize

*Shigenori MORITA**, *Junko YAMAGISHI***, *Jun ABE**
*Shinobu INANAGA**** and *Yukihiro SUGIMOTO****

* Graduate School of Agricultural and Life Sciences, The University of Tokyo

** Faculty of Agriculture, The University of Tokyo

*** Arid Land Research Center, Tottori University

High physiological activity of root system is quite important for improving crop production, especially under stressed conditions. However, it is not easy to estimate physiological activity of root system in a field. Authors measured bleeding rate as an indicator of physiological activity of a whole root system in field grown maize. Bleeding rate increased to reach the maximum at tasseling and then decreased somewhat. At the same time number and diameter of nodal roots were recorded after excavating basal part of root system. Both number and diameter were increasing with shoot growth though grain-filling stage. There was an intimate correlation between bleeding rate and morphological traits of root system before tasseling. Such a relationship, however, was not found after tasseling, possibly because partitioning was changed after tasseling.

Study on Pant Salt Tolerance by Metabolic Engineering of Glycinebetaine Accumulation in Rice

*Tetsuko TAKABE**, *Shinobu INANAGA*** and *Yukihiro SUGIMOTO***

* Bioscience Center, Nagoya University

** Arid Land Research Center, Tottori University

We have been studying on metabolic engineering of glycinebetaine synthesis and accumulation to improve salt tolerance of plants. We have obtained results as follows.

Rice transformed with peroxisomal betaine aldehyde dehydrogenase cDNA from barley converted betaine aldehyde to glycinebetaine and acquired an increased salinity tolerance of the leaves and roots. Then rice transformed with modified betA encoding choline dehydrogenase from *E. coli*, which can express in higher plants, accumulated glycinebetaine as high as barley and acquired highly increased salt tolerance. Transgenically produced glycinebetaine decreased salt influx into rice plants under salt stress.

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

*Hiromitsu NAKAJIMA**, *Yukihiro SUGIMOTO*** and *Shinobu INANAGA***

* Faculty of Agriculture, Tottori University

** Arid Land Research Center, Tottori University

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. Metabolites from 20 isolates were found to induce effective germination of the parasite.

Comparative Study on Factor of Soil Concerning Biological Products on Desert

*Kazuhisa HASEGAWA** and *Masao TOYAMA***

* Ishikawa Agricultural College

** Arid Land Research Center, Tottori University

More fertile soil condition was comparatively studied on especially sandy soil with soil humus.

Organic matter used in this study was made from abandoned wood chip/small tree. The pot experiment was carried out by applying it. As a result, spinach was grown better on sandy soil with fine rotten chip (woody compost) while increasing population of aerobic microbe at elevated temperatures.

Ecophysiological Studies on the Pine Wilt Disease Occurring in Coastal Sand Dunes

*Kazuyoshi FUTAI**, *Norikazu YAMANAKA***, *Shigenobu TAMAI*** and *Fukuju YAMAMOTO****

*Graduate School of Agriculture, Kyoto University

**Arid Land Research Center, Tottori University

***Faculty of Agriculture, Tottori University

The pine wilt disease occurring on coastal sand dunes has been investigated from some view points. The attack intensity of Japanese pine sawyer, the vector of pine wilt pathogen, was evaluated by counting the wounding marks on pine twigs, and was related to the suppression in internode elongation of the pine trees. To estimate how the pine wilt extend its distribution, the locations of newly-killed trees and those of stumps of previously-killed trees were plotted on the same map. The newly killed trees seem to locate in the vicinity to the previously-killed ones. These field studies were carried out at two 20 x 20m plots, one was treated with fertilizer, and the other was non-fertilized control. So far, however, no difference was found between these two plots. Mycorrhizal formation was also compared between these two plots by examining the roots of current-year-old pine seedlings planted artificially.

Ecophysiological Study on Drought Resistance of Tree Species in China

*Ken YOSHIKAWA**, *Takashi KUWADA**, *Ayako SEO** and *Shigenobu TAMAI***

*Faculty of Agriculture, Okayama University

**Arid Land Research Center, Tottori University

Water stress has some effects on physiological activity and growth of plants. Plants growing in arid and semi-arid region must have two types of drought tolerance, such as acute and chronic drought tolerance. The objective of this study was to examine the effects of acute water stress on some photosynthetic parameters, such as quantum yield, photochemical quenching and electron transfer reaction, of seven plants growing in semi-arid region of China comparing with three plants growing in Japan. Measurements of these chlorophyll a fluorescence are efficient indicators of photochemical activity of reaction center.

Sample plants growing in small pots were stored in a growth chamber at controlled air temperature (25-30 °C), humidity (30-40%) and light intensity without any irrigation for two weeks to experience various degrees of drought stress of soil condition, indicated by pF value. The some parameters were determined from chlorophyll a fluorescence using a pulse amplitude modulation fluorometer (Model MINI-PAM, Walz). Changes in quantum yield, photochemical quenching and electron transfer reaction with decreasing soil moisture content were monitored. Comparing these parameters, differences in sensitivity to soil drying was detected among sample plants. These difference could be interpreted as one of the drought resistance to maintain CO₂ assimilation even in severe soil moisture condition.

Basic Studies on Agricultural Books in the Islamic World

Kosuke SHIMIZU and Tahei YAMAMOTO***

* Faculty of Letters, Kyushu University

** Arid Land Research Center, Tottori University

The background of Persian agricultural book named *Irshad al-Zira* which was written in Heart in 1515 are discussed as a material of historical survey. It is supposed to have been prepared during the era of the Timurids. Its contents are mainly as follows; Selection of soil and time for cultivating, Cereals and manure, Vegetables, grapes, trees, and flowers, Care for trees and estimation of crops, Gardening, Knowledge of well experienced farmers.

The most important is one from farmers. Judging from the names of varieties of grapes, wheat, barley and other crops, the geographical background of *Irsad al-Zira* is confirmed to be the world around Heart, namely the eastern part of Iran and western part of Central Asia.

Studies for Optimal Operation of Sub-Surface Drainage System in Arid and Semi-arid Regions - For Salinity Control and Supplementary Sub-Surface Irrigation -

Niaz AHMAD, Yoshihiro KAIDA** and Tahei YAMAMOTO****

*JSPS Research Fellow (University of Agriculture, Faisalabad, Pakistan)

**Center for Southeast Asia Studies, Kyoto University

*** Arid Land Research Center, Tottori University

The use of sub-surface tile drainage system for sub-surface irrigation is not being practiced in arid and semi-arid regions. The major constraints to use sub-surface drainage system for sub-surface irrigation (controlled drainage) are low ground water quality and high risk of salinization under low rainfalls and high temperatures. On the other hand, free drainage from the tiles increases the demand of already scared surface irrigation water by acting as a water sink. Keeping the both points in view, studies were planned to investigate the wheat response for temporary shallow saline water (marginal) table during the high water demanded stages, i.e. late vegetative and earring. The study was conducted in a physical drainage model which consists of 6 lysimeters, each of size of 1.4 m wide and 3.6 long and 1.52 m deep, with a central water sump of 1.2 m in diameter to control water table in the individual lysimeter. The selected treatment included the water table depths of 30 cm from ground surface for 13 days at the late and earring stages of wheat with two replications. Whereas, during the rest part of the experiment, similar to the two lysimeters of controlled condition, surface irrigation was applied to each of the lysimeter at the 50 % depletion of available water (DAW). The results showed higher grain and straw yields of wheat from lysimeters treated with sub-surface irrigation in comparison with grain and straw yields obtained from surface irrigated lysimeters (control). The maximum grain yield (7430 kg ha^{-1}) was obtained from the lysimeters treated with high water table of 13 days at 30 cm during the late vegetative stage, followed by the lysimeters treated with high water table of the same depth and duration during the earring stage with grain yield of 7370 kg ha^{-1} and the lysimeters surface irrigated at 50 % DAW (6500 kg ha^{-1}). The results of the study

concluded that surface irrigation at 50 % DAW might not be enough to meet peak water requirements of wheat and support the use of controlled drainage systems for the sub-irrigation. But yet it is important to conduct more studies for different crops and salinity behavior under short durations of high saline water table for the optimum operation of drainage systems for sub-irrigation in arid and semi-arid regions.

Dynamics on Soil Moisture Variation by Temporal Underground Irrigation for Saving Water

*Sakae SHIBUSAWA**, *Akira SASAO***, *Naoko KUROHAMA**, and *Mitsuhiro INOUE****

* Graduate School of Bio-Applications and Systems Engineering,
Tokyo University of Agriculture and Technology

** Faculty of Agriculture, Tokyo University of Agriculture and Technology

*** Arid Land Research Center, Tottori University

Soil moisture movement in sandy soil was investigated in a case of tempering irrigation using transfer function technique. Porous irrigation pipes were imbedded at 0, 10 and 20 cm depths and five moisture sensors were set around each irrigation pipe in a vertical plane. Changing the irrigation interval and intensity, temporal variation of moisture was measured by 2 min sampling interval. Assuming the water supply as an impulsive input and the soil moisture obtained as an output, DFT analysis provided transfer functions that indicated frequency-dependent moisture transfer in the soil. Transfer functions estimated revealed that soil moisture just under the pipe directly responded to tempering irrigation so as to indicate clear peaks at periodical frequencies, and that those peaks became lower as the distance from the pipe was greater. Soil moisture just above the pipe tended to show less periodical variation without peaks over frequencies. With summation of power spectrum all over the frequencies on soil moisture at 15cm depth, it was found that 20cm pipe depth provided a small variation in soil moisture but the pipe on the ground surface induced a large variation. Transfer function technique has the worth to use for evaluating temporal and spatial variation of soil moisture induced by such tempering irrigation operation.

Estimation of Hydraulic Properties for Water Flow and Salt Transport

*Yasushi MORI**, *Yasutaka KIHARA** and *Mitsuhiro INOUE***

* Faculty of Life & Environmental Science, Shimane University

** Arid Land Research Center, Tottori University

Measuring unsaturated hydraulic conductivity and soil electrical conductivity (EC) has great importance when we manage the water movement and solute transport in saline soils. Multi-step outflow method for unsaturated hydraulic conductivity measurement and 4-electrode method for EC measurement were employed. Multi-step outflow experiments were carried out for three soils under different management; paddy field, upland field and forest soils. Parameter optimization was successful though they were collected from undisturbed conditions. However, for paddy field soils or other soils which showed preferential flow in dye method, differences in density between macropore and matrix gave unstable solutions. Because hydraulic conductivity in saturation or near saturation was affected by macropore while that in unsaturated conditions was affected by matrix domain. Parameter fitting was improved for those

type soils, if saturated hydraulic conductivity was also added to optimization parameters. Actually the unsaturated conductivity curve for those soils showed two-domain curve which was suggested by van Genuchten et al. 4-electrode method was carried out for Tottori dune sand. Traditional measurement of 1:5 dilution method and newly-developed 4-electrode method were compared, since 1:5 dilution needs core cutting during experiments, while 4-electrode method could monitor the real time solute transport in the soil column. A pencil type probe was developed for easy penetration into the soil. EC measurement by 4-electrode was precisely related to the traditional 1:5 dilution method under 2000mS/m. However, deviations from 1:1 line were found when soils were in dry conditions. 4-electrode method assumed that electric current is conducted in the soil, however in dry conditions, the assumption was not realized causing EC measurement unstable and sometimes impossible.

In-situ Measurement of Soil Permeability

Toshihiro MORII and Mitsuhiro INOUE***

*Faculty of Agriculture, Niigata University

**Arid Land Research Center, Tottori University

In-situ measurement of soil permeability was investigated in a sand-dune research field of the ALRC. A pressure infiltrometer, originally developed by Reynolds, W. D. and Elrick, D. E., Canada, was used to measure a field-saturated hydraulic conductivity of soil. Special features of the pressure infiltrometer are its simplicity of measurement and its portability in the field.

The field-saturated hydraulic conductivity of sand were measured by the pressure infiltrometer. Soil cores 100 cc in volume were sampled at the experiment site to determine the hydraulic conductivity of sand by using a laboratory permeability test. Mean of the hydraulic conductivity measured by the pressure infiltrometer was about 1.7 times as large as the one determined by the laboratory permeability test. Suction and moisture content within soil under the pressure infiltrometer were also monitored during the test. Numerical simulation agreed fairly well with the behavior of moisture monitored within the soil, which may support theoretical equations derived for the pressure infiltrometer test.

X-ray Microanalysis of Silicon Localization in Leaves, Fruits, Stems and Roots of Wheat (*Triticum aestivum* L.) Grown with or without Silicate

Eiichi TANIMOTO, Alexander LUX**, Miroslava LUXOVA**, Ryoichi YAMAMOTO***,
Donald J. NEVINS***, Emanuel EPSTEIN****, Keiko TSUKAMOTO**, Yukihiro SUGIMOTO**
and Shinobu INANAGA***

* Biomolecular Science, Institute of Natural Sciences, Nagoya City University

**Arid Land Research Center, Tottori University

***Dept. Vegetable Crops, University of California Davis

****Dept. Land, Air and Water Resources, University of California Davis

Silicon (Si) is the most abundant element in the soil. Although Si deprivation does not cause severe symptoms in plants, some physiological effects have been reported. It increases resistance against

microbial infection, promotes growth and affects physical property of awn surface. However it is unknown whether Si affects mechanical properties of cell walls in immature and growing organs.

In order to detect the Si-effect on the mechanical properties of cell walls, we have compared two wheat plants hydroponically cultured for 9 weeks with or without Si. For the first step of the study, we have quantitatively measured the localization and deposition of Si in wheat plants by X-ray microanalysis and SEM observation. Si largely deposited and formed typical shapes of Si body on the outer surface of epidermis in leaves, caryopses and stems but no thick deposition was detected in roots. In the Si deprived plants, no condensation and no Si-body structure was observed in the corresponding part of overground organs. Instead, there were pits or holes in the place of silica body in Si-deprived plants. The preliminary measurement of mechanical properties of leaf cell walls indicated that Si-deprived leaf was more extensible than that of Si applied plants. The result suggested that Si provides mechanical strength for growing leaves.