3.3 Joint Research

(1) List of Joint Research

A-1) Analysis of Surface Conditions in Arid Land by Remote Sensing

Analysis of Surface Conditions in Arid Land by Remote Sensing
- Monitoring the change of land classification and of biomass in Kagoshima prefecture -
Etsuji ISHIGURO, Muneharu SATO, Koichi IWASAKI, Sumitaka KASHIWAGI, Hideo IKEDA, Makio KAMICHIKA and Kyoichi OTSUKI

Estimation of Spatial Distribution of Vegetation Amount in a Watershed Using Landsat-5 TM Data
Masahiro SEGUCHI, Takayuki KOJIMA*, Makio KAMICHIKA** and Kyoichi OTSUKI***

Use of Disjunctive Cokriging to Estimate Soil Organic Matter from Landsat Thematic Mapper Image
Tomoyuki ISHIDA, Makio KAMICHIKA and Kyoichi OTSUKI

A-2) Hydraulic Design and Water Management of Microirrigation

Development of chemical injection in microirrigation system using the bend pipe
Soichi NISHIYAMA and Tomohisa YANO

The Management of Fingering Flow Occurring under Drip Irrigation
Hiroyuki CHO and Tomohisa YANO

Dynamic Analysis of Soil Moisture for Micro Irrigation
Shouhei WATANABE and Tomohisa YANO

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

Characteristics of Root System in Upland Rice Associated with Sustainable Grain Production in Drought-Stressed Conditions.
Jun ABE, Junko YAMAGISHI, Shinobu INANAGA and Yukihiro SUGIMOTO

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

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

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

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

Evaluation of Water Content of Plant by Remote Sensing
Hiroshi TANI, Seiji HAYAKAWA, Makio KAMICHIKA and Kyoichi OTSUKI

Functional Analysis of Water Uptake from Tree Root System
Tatsuaki KOBAYASHI and Shigenobu TAMAI

Growth of *Sabina vulgaris* under water stresses with culture solution.
Ken YOSHIKAWA, Miwako ZUSHI and Sigenobu TAMAI

Studies on Evapotranspiration under Drip Conditions :
Water Requirements of Drip-irrigated Cabbage at Coastal Arid Lands
Kazuro MOMII, Kyoichi OTSUKI and Tomohisa YANO

B-2) Measurement of Evapotranspiration and Photosynthesis on the Crop Canopy

Numerical Experiment of Vegetation Structure Effect on the Photosynthesis by using Soil-Plant-Air System Model (NEO SPAM)
Tetsuya KAWAMURA, Makio KAMICHIKA, Mayumi YOSHIMOTO and Yoshinobu HARAZONO

Measurement of Water Vapor Flux Using the Micrometeorological Methods
Hiromichi ODANI and Tomohisa YANO

A Relationship between Soil Moisture Deficit of Root Zone and Evapotranspiration on an Upland Field
Koji INOSAKO and Tomohisa YANO

C) Free Subject on Arid Land Studies

Study on the Use of Renewable Energy and Environmental Conservation in Arid Area
Hikaru TSUTSUI, Nobumasa HATCHO, Kyoichi OTSUKI and Makio KAMICHIKA

Dynamics on Soil Moisture Variation by Temporal Underground Irrigation for Saving Water
Sakae SHIBUSAWA, Akira SASANO, Nozomu OSHIMA and Mitsuhiro INOUE

Basic Studies on Agricultural Books in the Islamic World
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***In-situ* Measurement of Moisture Properties of Unsaturated Soils**
Toshihiro MORII and Mitsuhiro INOUE

Comparative Study on Factor of Soil Concerning Biological Products on Desert

Kazuhisa HASEGAWA and Masao TOYAMA

(2) Summary of Joint Research

A-1) Analysis of Surface Conditions in Arid Land by Remote Sensing

Analysis of Surface Conditions in Arid Land by Remote Sensing
- Monitoring the change of land usage and biomass in Kagoshima prefecture-

Etsuji ISHIGURO, Muneharu SATO*, Koichi IWASAKI*, Sumitaka KASHIWAGI*, Hideo IKEDA**
*Makio KAMICHIKA** and Kyoichi OTSUKI***

* Faculty of Agriculture, Kagoshima University
** Arid Land Research Center, Tottori University

This study is to confirm the possibility of monitoring and analyzing the change of the environment in Kagoshima prefecture, especially the forest and upland area using satellite data. By land-classification for the area of Kagoshima city and Ibusuki city with Landsat-5/TM data, it is clarified that the forest area and upland field decreased during the years from 1983 to 1992. NDVI and RVI, derived from the results of measured spectro-reflectance of weeds showed the high correlation to the dry weight of weeds. This result suggests the effectiveness to evaluate the biomass using Landsat-5/TM data. The images which are composed by NDVI and RVI with Landsat-5/TM data for the forest and upland fields showed the decreasing tendency in biomass in these period in Kagoshima city. On the other hand, the same images in the Ibusuki city showed the increasing tendency in biomass. These results show the possibility of evaluating the biomass using satellite data.

Estimation of Spatial Distribution of Vegetation Amount in a Watershed Using Landsat-5 TM Data

Masahiro SEGUCHI, Takayuki KOJIMA*, Makio KAMICHIKA** and Kyoichi OTSUKI***

* Faculty of Agriculture, Saga University
** Arid Land Research Center, Tottori University

This study discussed the method for indicating the spatial distribution of vegetation amount in a watershed by means of LAI(Leaf Area Index) from a TM image data of Landsat-5. First of all, the relationships between LAI and vegetation canopy spectra were investigated on the basis of the obtained experimental data. As a result, a high correlation between LAI and NDVI(Normalized Difference Vegetation Index) was found and this relation was expressed by an equation. Next, the LAI image of a study basin was obtained from a TM image data of Landsat-5 on the basis of the relationship between LAI and NDVI. The LAI image made it possible to estimate the spatial distribution of vegetation amount in a watershed.

Use of Disjunctive Cokriging to Estimate Soil Organic Matter from Landsat Thematic Mapper Image

Tomoyuki ISHIDA, Makio KAMICHIKA** and Kyoichi OTSUKI***

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In Japan, it has recently been required to grow crops other than paddy rice in the paddy fields, since the demand for rice has decreased. This study was carried out in order to obtain information for a decision on paddy fields where other crops than paddy rice should be planted. This decision is based on the knowledge that the necessary amounts of soil organic matter are different between paddy rice and other crops. Detailed descriptions of the spatial variability of soil organic matter is, therefore, desirable in this decision. The spatial variability in the Aizu Basin, northern Japan, was predicted using disjunctive cokriging. The disjunctive cokriging estimator used soil sample data as the variate, and as the covariate, estimates of soil organic matter obtained from Landsat Thematic Mapper images of submerged paddies. For the estimation from the imaginary, the soil organic matter content could be estimated from multi-band data through the resulting prediction equation. The performance of disjunctive cokriging was evaluated and compared with that of traditional regression analyses using the resulting prediction equations and those of simple and disjunctive kriging, using cross-validation.

A-2) Hydraulic Design and Water Management of Microirrigation

Development of chemical injection in microirrigation system using the bend pipe

Soichi NISHIYAMA and Tomohisa YANO***

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To reduce the price of agricultural production, low cost and low energy are request in agricultural facility.

The hydraulic characteristics of bend flow and bypass flow combined inside and outside point of curve pipe were investigated. Bypass flow is generated by pressure head difference between inside and out side of bend pipe. This difference is caused by centrifugal force of water flow in curve pipe. The discharge of bypass flow is proportional to the main flow discharge under the limited condition. In this flow region, we can apply bypass flow to chemical injection in microirrigation system.

Bypass flow discharge depends on not only main flow discharge but also hydraulic resistance of bypass route. The theoretical analysis was carried out.

The Management of Fingering Flow Occurring under Drip Irrigation

Hiroyuki CHO and Tomohisa YANO***

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Drip irrigation in dry soils may provoke wetting front instability. As a result, substantial amounts of water may rapidly reach large depth, bypassing the root zone. Wetting fronts can become unstable whenever the near-saturated hydraulic conductivity exceeds the infiltration rate in a dry soil (e.g. under non-ponding irrigation or ponding infiltration into a profile with a poorly conducting top layer). Numerical modeling of this process is in its infancy.

We used 2D and 3D containers with a fine-over-coarse packing of glass beads to study fingered flow. By using a wide variety of glass bead sizes and infiltration rates, we could identify the effect of both on finger occurrence and size. Theoretical expressions for finger size were valid for a limited range of infiltration rates only. Experiments in natural soils are required to quantify water losses caused by fingering in the field.

Dynamic Analysis of Soil Moisture for Micro Irrigation

Shouhei WATANABE and Tomohisa YANO***

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Soil moisture behavior from a line source in micro irrigation is considered to be two dimensional. Finite Element Method (FEM) is often employed for simulation. In this study, the accuracy of analyzing with FEM in comparison with an analytical solution is evaluated. These two methods are compared under as similar conditions as possible because exactly the same ones cannot be achieved. With the appropriate data available, such as element division, time period and soil moisture characteristics, the following conclusion was obtained : the accuracy of analyzing soil moisture behavior from a line source with FEM was quite high except near the bottom of a calculation region.

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

Rice cultivars of different drought resistance were grown under progressing drought and rewatering conditions to evaluate seminal root system responses. In general, lateral root development showed sharper responses than seminal root axis elongation growth. Under drought stress, L-type lateral root development was remarkably promoted especially for drought resistant cultivars. The same responses to rewatering were also distinguishable for the L-type lateral roots. Subsequently, rooting was artificially controlled at various growth stages to produce plants with different root system sizes, and the seminal root development was compared among the plants. Results revealed that plants with smaller root system size developed more vigorous seminal root system. Comparison between crops with high drought resistance and the ones that are adapted to relatively wet conditions (pearl millet vs. Job's tear, upland vs. lowland rice) showed that such plastic development was more markedly expressed under drought conditions than well-watered conditions for the former crops, and the reverse trend was evident for the latter crops. In such response as well, L-type lateral roots played a major role. These facts clearly suggest that the plastic development of lateral roots, especially L-type ones is one of the key characteristics for the plant's expression of drought resistance.

Characteristics of Root System in Upland Rice Associated with Sustainable Grain Production in Drought-Stressed Conditions.

Jun ABE, Junko YAMAGUCHI**, 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

It was shown in previous studies that development of roots in deep soil layer could be important to maintain grain yield of upland rice under drought conditions. Thus, shoot characteristics of upland rice cultivars were investigated in view of relationship to vertical distribution of roots in a field experiment. Besides, anatomical characteristics of roots taken from deep and shallow soil layers were compared to each other. The result indicated that diameter of stems has positive correlation with root volume in deep soil layers. This suggests a possibility to use stem diameter as an index to select drought tolerant cultivars of upland rice. A different aging of roots depending on soil depth were clear at harvesting stage. Anatomical observations of root cross-sections with a fluorescence microscope and a scanning electron microscope (SEM) visualized remarkable accumulation of lignin on cell walls of roots taken from shallow soil layers, which should be a barrier to water influx. This suggests high contribution of roots in deep soil layers to water uptake at late growth stage of upland rice.

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

The Study on Growth of Transgenic Rice Plants Producing Glycinebetaine in Sea Water

Tetsuko TAKABE and Yoshichika TAKEUCHI***

* Bioscience Center, Nagoya University
** Arid Land Research Center, Tottori University

We introduced modified *bet n* gene encoding choline dehydrogenase from *Escherichia coli* into rice plants. Modified *bet n* protein was targeted to chloroplasts, mitochondria and cytosol. Both chloroplast and mitochondria-targeted transgenic rice plants produced glycinebetaine (1 μ mole/gFW), but cytosol-targetted rice plants did not produce glycinebetaine. This is consistent with that *bet n* can function linked with electron transport system in *E. coli*. These transgenic rice plants acquired an increased salinity tolerance compared with control plants. In 150 mM NaCl, the transgenic rice plants can germinate, grow slowly and make seeds. We will test salinity tolerance of these transgenic rice plants using sea water in more detail next year.

Effect of Soil Water Deficit on Carotene Formation and Vitamin C Content of Cherry Tomato

Naotaka MATSUZOE and Yoshichika TAKEUCHI***

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This experiment is to clear the effect of soil water deficit on carotene formation and vitamin C content of fruit, and to examine relation between cropping season and cultivars. Four tomato cultivars were used in this study; 'Mini carol' (fruit color : red type), 'Cherry pink' (pink type), 'Yellow carol' and 'Orange carol' (pink types). The effect of soil water deficit on fruit coloring in the fall cropping was greater than that in the spring one. On the red and pink type tomato, even when the amount of lycopene per dry fruit weight increased by soil water deficit, that of β-carotene decreased by the treatment. This fact indicated that the effect of soil water deficit on lycopene formation in tomato fruit was different from that of β-carotene formation. The ratio of the increase of lycopene content (dry/control treatment) was greater in the fall cropping than that in spring one. Vitamin C content per fresh weight in fruit tended to increase slightly by soil water deficit in almost all cultivars. On the other hand, vitamin C content per dry weight decreased, and the effect of soil water deficit on vitamin C content varied depending on each cropping season.

Effects of Salt Water lrrigation on Growth of Spring-planting Flower Geophytes

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* Faculty of Agriculture, Kyushu University
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Effects of salt concentration in irrigation water on growth of tuberose (Polianthes tuberosa), a geophyte of subtropical origin, were investigated. The corms of the plant, 7.8cm in circumference, were planted in sand in plastic pots (23cm in diameter) on 14 May 1996 and grown in a greenhouse. Tap water was applied for 40 days until flower buds developed in the corms. On 23 June, when watering I Iiter of O, 100, 500, 1,000 or 5,000 ml-1 salt water was applied per pot.

Higher the salt concentration in water was, Iower the plant height became. At the highest concentration (5,000 ml-1) in this experiment, the plant height was 73% of the control, but there were no decrease in number of leaves and percentage of flowering. Number of lateral buds on the corms were not different among the treatments, but the growth and number of leaves from the lateral buds were inhibited by the salt water. The result in this experiment shows that the plant has rather high tolerance to salt and the salt water treatment may produce the plants short suitable for potted plants without applying any chemical growth retardant.

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***

* College of Agriculture, University of the Ryukyus
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The behavior for salinity and salt-hardening effect to the mangrove trees was studied to use an Okinawan mangrove tree, *Kandelia candel* Druce, in a greenhouse at University of the Ryukyus, Okinawa. The soil salinity was adjusted to 1.8% and 3.6% level by addition of sodium chloride to the nutrient solution. The comparative condition was non-salt nutrient solution. After three months growth period of pretreatment, more than 5% salt solution was added to the all growing conditions.

Before the treatment of high salt solution, sodium content in the seedlings under salt conditions were 10 to 13 times the one under non-salt condition. On the contrary, potassium content in the seedlings under non-salt conditions was higher than the ones under salt conditions. After the treatment of high salt solution, sodium content in the seedlings under non-salt condition increased by 5 to 7 times that of pretreatment but the ones under salt conditions did not change apparently. The potassium content decreased in the seedling under non-salt condition, and it increased under salt conditions by the added high salt solution. And, salt content in the seedling under non-salt and 1.8% salt condition was high in the root part, but under 3.6% salt condition, salt content diffused to the both part, root and shoot of the seedling. By the cause of these result, mortality of the seedling under the non-salt and 1.8% salt condition was 100% on 11 days after the treatment, but, it was about 20% under the 3.6% salt condition.

Planting of *Salix psammophila* Cuttings in Various Ways and of Several Sizes

Masazo TOKUOKA and Shigenobu TAMAI***

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We planted various sizes of *Salix psammophila* cuttings in various ways to clarify the best method of planting. (1) The methods we tested were, 1.Arch style (AS) : bending the cuttings and planting both ends, 2.U-shape (US) : bending the cuttings into a U-shape and planting the middle part, 3.Covering both ends of the cuttings with soil (CE), 4.Total burial (TB) , 5.Control (CO) : planting by the ordinary method. (2) We planted cuttings 40, 100 or 180 cm in length to determine the optimal cutting size. The results of the tests were as follow:

(1) The AS and CE cuttings produced roots not only at the bottom but also at the top ends, and the total number of roots per rooted cutting was equivalent to or more than that of CO cuttings.
(2) 100% rooting rates were obtained. Irrespective of rooted cutting size, the longer the cutting, the greater the dry weight of roots or leaves, and the greater the mean root length were obtained. The arch style of planting is resistant to high wind and has certain advantages. Thus it appears that planting large cuttings in Arch style is the most desirable.

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

Numerical Simulation of Solute Transport in a Two-dimensional Heterogeneous Field

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Field-scale solute transport is highly heterogeneous due to the inherent spatial variability of soils. Two-dimensional hypothetical fields were generated using a random Miller scaling factor for heterogeneous hydraulic properties in the fields. Numerical experiments based on Richards equation and the convection dispersion equation (CDE) were conducted to investigate reactive and nonreactive solute transport under unsaturated steady state water flow conditions. The predictions of two one-dimensional transport models, namely the CDE and the stochastic-convective stream tube model (STM), were tested for area-averaged mean transport. Since the transport in hypothetical fields was less heterogeneous compared to the actual field experimental data, the limitations of the scaling assumptions for heterogeneous unsaturated flow were discussed. When the linear distribution coefficient for concentration vs. adsorption is also heterogeneous in the field, negative correlation's between adsorption and the saturated conductivity resulted in greater solute spreading. It is necessary to further investigate heterogeneous reactive solute transport especially for unsaturated water flow conditions.

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

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** Arid Land Research Center, Tottori University

In 1996, annual precipitations were 2400 mm, 2650 mm and maximum intensity were 62.5 mm/hr, 42.5 mm/hr at the university campus and Tano-cho, respectively. Vegetation of Shirasu slopes covered by non-woven fabric was remarkable, especially in bush clover. To understand the activity of root zone covered by non-woven fabric, biomass C,N, Total C , N and organic matter content and the number of bacteria and fungi for samples obtained from root zone at vegetation slopes of Shirasu soil in local upland fields were tested. There were high correlations ($r > 0.823$) between total C-total N, total N-biomass N and total C- biomass C, and total C had high correlations ($r > 0.780$) between other factors. Colonies of bacteria and fungi increased remarkably as compared with general surface soil-bare Kuroboku etc.

Research on Conservation of the Shallow Groundwater Resources

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The unsaturated soil hydraulic properties are essential data to predict the seepage behavior in the vadose zone to promote the shallow groundwater resources. In this study, a new experimental methodology of determining these properties is developed. 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 identified by Genetic algorithm incorporating finite element analysis of one-dimensional non steady seepage flow. The advantages of the proposed method are in the possibility of identifying the optimal saturated hydraulic conductivity and unsaturated soil hydraulic properties and diminishing experimental time. To evaluate availability of our proposed method, experimental results which are determined by proposed method and conventional method are compared for decomposed granite soil.

Preferential Flows and Solutes Transport in Sandy Soils

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In sandy soils that are very dry or water-repellent, the wetting front during infiltration may become unstable. In that case, preferential flow paths (fingers) form that rapidly transport water and solutes to deeper soil layers and, eventually, to the groundwater. Experiments reported in the literature indicate that fingers widen or even dissipate in moist subsoils. This process greatly affects solute leaching, and a proper understanding of its physical nature is of importance in the development of mathematical flow and transport models.

Under natural conditions, finger formation in the topsoil and finger widening/dissipation in the subsoil can occur in areas with extremely dry or water-repellent topsoils while the subsoil is at equilibrium with a shallow groundwater table. We reproduced these conditions in the laboratory by filling a 1 cm wide, transparent chamber with dry glass beads. Water was allowed to infiltrate through 52 drainage outlets in the chamber bottom to create a capillary fringe. A fine-textured layer was added on the top, and a dye solution was ponded at a constant level on the surface. Fingers rapidly formed in the topsoil. Upon entering the subsoil, the flow widened dramatically. Tensiometer readings below the dry-wet interface showed a pressure head profile consistent with conventional flow, suggesting the fingers dissipated instead of widened in the wetted soil. The relatively even distribution of drainage over the drainage outlets provided additional support for this conclusion.

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

Evaluation of Water Content of Plant by Remote Sensing

Hiroshi TANI, Seiji HAYAKAWA*, Makio KAMICHIKA** and Kyoichi OTSUKI***

* Faculty of Agriculture, Yamaguchi University
** Arid Land Research Center, Tottori University

Changes of normalized difference vegetation index (NDVI) obtained from spectral reflectance measurement were analyzed in order to investigate plant response to water or salty stress. In the present study, spectral measurements of rice (Nipponbare) exposed to artificial salty wind at five to thirty days after heading time were performed several times in the ripening stage. NDVI of rice exposed to salty wind at over fifteen days after heading, decreased quickly from about 0.8 to 0.4 in ten to fifteen days after exposed, while VI of control indicated about 0.8 and decreased gradually in the same period. On the other hand, rice exposed at five days after heading showed that NDVI fell down from 0.8 to 0.7 quickly and decreased gradually to 0.6 in the ripening stage, but little yield was given.

Functional Analysis of Water Uptake from Tree Root System

Tatsuaki KOBAYASHI and Shigenobu TAMAI***

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** Arid Land Research Center, Tottori University

The dynamics of water uptake of *Poplus* saplings were analyzed through the course of soil drying using the root system model. The modal part of water uptake has moved downward before the value of leaf water potential decreased. After the beginning of stomatal closure due to water stress, water uptake decreased in all layers of soil. Conductance of water uptake by each root has not so changed in the region of soil moisture condition more than -0.1 MPa. When the soil water potential decreased less than -0.1 MPa, conductance of water uptake declined sharply. It should be related to the development of disconnection of matric water among soil particles and roots.

Growth of *Sabina vulgaris* under water stresses with culture solution

Ken YOSHIKAWA, Miwako ZUSHI* and Sigenobu TAMAI***

* Faculty of Agriculture, Okayama University
** Arid Land Research Center, Tottori University

Sabina vulgaris was a tree species living in semi-arid region of China and seemed to have fairly great draught tolerance. However, the way of adaptation of *S. vulgaris* to the water stress to maintain its normal physiological activity was not still analyzed in detail under the severe environmental conditions. In this experiment, seedlings of *S. vulgaris* were planted in containers filled with small stones and culture solutions regulated the osmotic pressure in three levels by PEG. Such chronic water stresses were continued for about two years and the growth rate and leaf water relations of *S. vulgaris* was measured.

Elongation of apical shoot of seedlings were observed at two times, namely from March to May, and from July to September. Although there was not a remarkable difference in apical elongation at the first growth period among three treatment levels, the second growth from July to September was suppressed under severe water stress. In general, both elongation and diameter growth of stems were restrained with water stress. Seedlings of *S. vulgaris* showed a slight evidence of osmotic adjustment. Under severe water stresses, the bulk moduls of elasticity of leaf tissue was decreased, which meant the increase of cell wall elasticity, to maintain the constant level of leaf water potential during the decrease of tissue water content.

Studies on Evapotranspiration under Drip Conditions :
Water Requirements of Drip-irrigated Cabbage at Coastal Arid Lands

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**Arid Land Research Center, Tottori University

The irrigation water requirements of cabbage for maximum yield with minimum water use were investigated based on meteorological conditions and soil moisture dynamics at coastal areas in California peninsula, Mexico. Six water levels corresponding to 0.9, 1.3, 1.45, 1.7, 1.8, and 1.9 ETp (ETp = potential evapotranspiration calculated from the Penman method) were applied as irrigation water under drip conditions. The yield of cabbage at the water levels of 0.9 and 1.3 ETp was low in comparison with that at 1.45 ETp. No significant yield differences were obtained between the 1.45 and 1.9 ETp levels. Under these conditions, the 1.45 ETp is shown to be the optimal water requirement of cabbage for saving water and obtaining high yield. It was also found that the soil moisture depletion in the root zone of cabbage was about 1.5 times the potential evapotranspiration.

B-2) Measurement of Evapotranspiration and Photosynthesis on the Crop Canopy

Numerical Experiment of Vegetation Structure Effect on the Photosynthesis using Soil-Plant-Air System Model (NEO SPAM)

Tetsuya KAWAMURA, Makio KAMICHIKA**,*
*Mayumi YOSHIMOTO*** and Yoshinobu HARAZONO****

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The effects of canopy structure on the mass transfer between the atmosphere and vegetation were studied by two dimensional numerical experiment with Soil-Plant-Air system Model (NEO-SPAM) for three different types of soybean canopy. Leaf Area Index (LAI) of the vegetation was changed from 1.35 for the young vegetation to 9.77 for the matured vegetation. Flow variables such as wind speed above and inside the vegetation was simulated reasonably. The wind speed of the young vegetation was greater at the bottom of canopy due to its sparse density of leaves. The eddy viscosity coefficient K and the penetration of solar radiation in the young vegetation were greater than that of the matured. The photosynthetic rate per leaf area was 5 times higher at the young case than that of matured, which was caused by both effects of higher values of K and Rs. The light use efficiency, which was examined by comparing of photosynthetic rate at the same solar radiation levels, was 35% higher at the young case than that of matured.

Measurement of Water Vapor Flux Using the Micrometeorological Methods

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In the energy balance Bowen ratio method, various inapplicable conditions were shown in terms of the inconsistencies in positive and negative values between the temperature difference and the sensible heat flux, and between the vapor pressure difference and the vapor flux. Temperatures and vapor pressures at two heights were measured over a rice field at Shiga Prefectural Junior College, and sensible heat and vapor fluxes were estimated using the energy balance Bowen ratio method. Many inapplicable measurements were found in conditions of $T_1-T_2<0$, $e_1-e_2>0$, $0>\beta>-1$, and $Rn-G<0$ (T is temperature, e is vapor pressure, β is the Bowen ratio, Rn is net radiation, and G is soil heat flux).

In the aerodynamic method, the zero-plane displacement heights for the temperature profile were calculated with the temperature and vapor pressure and the flux-profle relationships. The friction velocity and the sensible heat flux in these relationships were measured with the eddy correlation method. Calculated values of the displacemennt height ranged from 0.64•h to 1.02•h (h is crop height), which was very close to that for the wind profile (0.7•h to 1.0•h). However, since it is considered that the temperature and vapor pressure measurements were subject to the imperfectness of a radiation shield, the displacement heights for temperature profile would be close to 0.7•h.

A Relationship between Soil Moisture Deficit of Root Zone and Evapotranspiration on an Upland Field

Koji INOSAKO and Tomohisa YANO***

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Prediction of evapotranspiration is important for the field irrigation engineering. The Bowen ratio method can estimate latent heat flux during the day, exactly. This method is not practical since it requires many kinds of observed data.

Therefore the Penman method (ETp) or the equilibrium evaporation (Eeq) method have utilized in the irrigation engineering. Actual evapotranspiration is estimated to multiply by a correct efficiency in this field. An optical growth of canopy is a precondition in this method. Therefore there aren't any reports on evapotranspiration on a canopy inhibited growth.

In this study, soil moisture, micrometeorology and crop data (LAI, crop height, depth of root zone) were observed at sorghum field inhibited growth. The stomatal resistance was estimated by the Penman-Monteith method. Furthermore it is discussed about application this engineering method to this case. Results in this study are summarized as follows: 1) Evapotranspiration rate is regulated under the good condition of soil moisture and micrometeorology since a stomatal resistance of sorghum canopy inhibited growth increases greatly. 2) The daily actual evapotranspiration on this field can be predicted in good accuracy by the method multiplied ETp and Eeq by correct efficiencies.

C) Free Subject on Arid Land Studies

Study on the Use of Renewable Energy and Environmental Conservation in Arid Area

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In many arid regions, excessive and inappropriate use of resources has resulted in the increased load on environment, which is the major factor of environmental degradation. Salinization, for example, is the result of inappropriate use and management of water resource. The present study focuses on identifying possible measures to enable effective and appropriate use of resources so that both regional development and environmental conservation could be achieved.

In the Aral sea region, the role of cultivating paddy for leaching purpose has been analyzed. The change of crop rotation pattern of paddy from 3 out of 6 years (50%) to 2 out of 6 years (33.3%) can reduce seasonal water demand as much as 10% and match regional demand for food. In allocating valuable water, not only maximizing production but marginal benefit of producing certain crop, yield reduction by below-optimal irrigation, tolerance of crop to salt damage need to be analyzed. In addition to technical problems of water management, institutional capacity needs to be carefully assessed under transition period to market-oriented economy. New institution of water management, such as water user association has to replace functions of Colhoze/Sohoze.

With regard to effective use of waste water such as highly-saline drainage water, analyses were made for possible desalinization through the use of solar heat and energy. Solar heat can be collected by polyethylene green house, which promotes evaporation, and vapor can be circulated through a fan to cooling device, where vapor is condensed to water. The fan is powered by photovoltaic cells.

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

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Using the technique for transfer function in linear systems, soil moisture movement in a temporal underground irrigation system was investigated. Vegetation and non-vegetation plots of sandy soil with porous irrigation pipes imbedded at 0, 10 and 20 cm depths were prepared in the greenhouse of the Arid Land Research Center. Experimental parameters were irrigation interval, irrigation water flow and depth of pipe imbedded. Impulsive water irrigation through the pipes and detecting moisture and matric potential at several depths at the same time, gave the impulse response of moisture movement through the test field soil. Assuming the water supply as an impulsive input and the soil moisture obtained as an output in the moisture transfer system of the test soil, FFT analysis provided the transfer function of the system. Transfer functions obtained showed the properties of frequency response of transient moisture flow in the soil, integrating the effects of distance or depth, magnitude of mass flow as well as the permeability of

soil.

Basic Studies on Agricultural Books in the Islamic World

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There were many Arabic agricultural books in the medieval Islamic world. Some of them were written in Andalus (Islamic Spain) and brought to other countries. But, few books were written in Persian in this field.

We chose one Persian agricultural book named Irshad al-Zira a as a material of historical survey. It was written in Herat in 1515. The author Abu Nasri Harawi wrote this book by collecting the information from peasants (muzarian) by oral inquiry. We found precious descriptions about agricultural affairs and social situations of the area around Herat .

In-situ Measurement of Moisture Properties of Unsaturated Soils

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As a preliminary study for developing the *in-situ* measurement, the applicability of the pressure infiltrometer was investigated. The pressure infiltrometer was originally developed at Guelph University, Canada, to measure the field-saturated hydraulic conductivity. Special feature of the pressure infiltrometer is its simplicity of measurement and its portability in the field. Theoretical equation to calculate the field-saturated hydraulic conductivity is derived based on the assumption of an exponential relation between the negative pressure head and the unsaturated hydraulic conductivity. Two attachments with a diameter about 11 and 5 cm was manufactured for trial experiments. The values of the field-saturated hydraulic conductivity estimated by the pressure infiltrometer were compared with the ones measured by the falling-head permeability tests in the laboratory, and the parameter α^* which describes the relative magnitude of the capillarity and gravity components of water flow through unsaturated soil was evaluated. It has been shown that α^* from 0.36/cm to 0.42/cm is applicable to the sand field.

Comparative Study on Factor of Soil Concerning Biological Products on Desert

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It was examined that effect of new water retaining agent produced from microbe made of biological waste matter on plant cultivation by Neubauer's seedling test in sandy soil. The sample contained 30% of new water retaining agent was more effective on plant cultivation in comparison with goods on the market

on both water content in soil and plant growth.