

1. Summaries of Doctor Theses

Study of sand movement in Tottori Sand Dune, Japan

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The natural monument area in Tottori Sand Dune is in a serious situation of weeding by machine to maintain the posture of "active" dune. It is preferable to maintain the dune as an original active state by the natural energy. To keep the environment in such a state, the dune state of the past have to be clarified, the mechanism between afforestation and the change to grassland have to be clear and primary factors which are related to sand movement have to be analyzed.

This study was conducted in the natural monument area in Tottori Sand Dune to contribute the activation of sand movement as well as the future forecast of the sand dune. The study was also intended the application onto a desertification study. The outline was described as follows.

In the first chapter, the outline of the investigation field was explained. A general view was introduced and the studies of sand movement in dune and desert, and of dune topography movement were summarized.

In the second chapter, the climate of Tottori Sand Dune, namely results of wind observation are discussed. In the first section, attention was paid to the wind that was an important factor of sand movement and dune topography movement. Wind climate around Tottori Sand Dune was analyzed, based on the meteorological data in Arid Land Research Center, Tottori University. As a result, it was confirmed that the wind directions that govern sand movement in Tottori Sand Dune were the northern side, especially NW, NNW and N. In the second section, the meteorological data for past 45 years in Arid Land Research Center were used. The influences of the windbreak forest growth to meteorological environment of dune were analyzed. As a result, a reduction of wind speed, a decrease of diurnal range and an increase of relative humidity were found. In the third section, mobile observation of wind speed and direction were conducted to specify the strong and weak wind area, and to clarify the distribution of wind directions in the field. As a result, wind environment in dune were surfaced the influence of topography and natural feature, such as mainly transverse dune and windbreak forest and so on. Even a small mound or a hollow could affect the wind speed and direction. In addition, some wind routes in the dune were cleared by the results of analysis for various direction of general wind.

In the third chapter, the result of the surface level change investigation that has been conducted monthly from 1992 in the field was analyzed. In this chapter, 1) sand movement in the field, 2) relation between sand movement and meteorological factors, 3) the influence of weeding to surface change were discussed based on the results of the surface change investigation between 1992-1998, meteorological data and weeding data. The absolute amounts of surface level change were bigger as the magnification of weeding area. It was cleared that surface changes were turned severe by weeding. The connection among weeding, topography, windbreak forests and surface changes were cleared by making the contour maps of the surface change distributions. By the comparison of surface change of each investigation stake with weeding area, it was cleared that not only weeding area but also south side of weeding area, surface changes become active, and the influence of weeding was small in north side.

In the fourth chapter, the information gotten from sand particle was analyzed. The granulometric

analysis was conducted to 119 points sand in all over the field. Median diameter and sorting coefficient were used as the index and analyzed with the observational result of wind speed and wind direction (the chapter 2). As a result, it is cleared that grain size distributions of sand reflect the effect of wind environment, topography, and vegetation. In addition, the relation between grain size distribution and accumulation pattern of sand were suggested. It is cleared that wind environment and sand accumulation pattern would be estimated by grain size distribution according to these results.

In the fifth chapter, remote sensing techniques were applied to analyze dune topography movements. The monitoring of dune topography was conducted by image processing using monochromic aerial photographs in 1970, 1981 and 1990. The aerial photographs have advantages; 1) there are many stocks of the historical photographs, 2) they can be readily purchased and 3) the resolution of the photograph is sufficiently high. Although, identification of the ridge part was hard because of gentle slope, it was found that slip face, which was formed to leeward slope of dune topographies, is repose angle and easily identified by difference of properties of brightness values. The slip faces were identified and colored another color in some photographs, and these images were made by overlay to one image. In this way, horizontal movements of dune topographies were visualized and the distances of movement were calculated. The movements of same topography in some 1/2000 maps were copied to one paper, and the movement distances of aerial photographs and maps were compared. As a result, it was confirmed that image processing of aerial photographs was useful to the monitoring of dune topographies. In addition, the chronological cut down area of wind break forest and the movement of coastline were visualized using similar exchange of brightness value.

The sixth chapter is the conclusion of all these results mentioned above.

These results are contributed to the analysis about the movement of sand dune, the mechanism of weeding and the factors affect sand movement in Tottori Sand Dune. The analysis methods used in this study are able to apply to the desertification area.

Biosynthesis of chlorine-containing compounds in *Menispermum dauricum* root cultures

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Halogen-containing compounds are found frequently in marine algae, fungi, bacteria, and rarely in higher plants. Up to now haloperoxidases, enzymes catalyzing the formation of carbon halogen bonds, have been reported from these living organisms except higher plants.

Menispermum dauricum root cultures provide a good system to study on biosynthesis and mechanism of chlorinated compounds, since they produce acutumine, a chlorinated benzyloisoquinoline alkaloid, and its dechloro analogue, dechloroacutumine. The effects of chloride ion on production of acutumine and dechloroacutumine by the root cultures were studied. The chloride ion contents in the medium play a key role in production of both alkaloids. A medium with low chloride contents promoted production of dechloroacutumine and suppressed that of acutumine. Production of the two alkaloids during the 60 days culture period was closely associated with root biomass. Both alkaloids accumulated in the roots and a relatively small proportion was exuded into the medium. The intact plant produced very little amounts of both alkaloids. On the average cultured roots contained 22 and 75-fold more acutumine and dechloroacutumine, respectively, than intact plants.

The biosynthetic relationship between acutumine and dechloroacutumine was studied using ^{13}C -labeled tyrosine and ^3H -labeled dechloroacutumine as tracers. ^{13}C NMR spectra of ^{13}C -labeled acutumine and dechloroacutumine showed that the alkaloids, each composed of two molecules of tyrosine, are derived from the same biosynthetic pathway. Feeding *M. dauricum* roots, cultured in a chloride-enriched medium, with ^3H -labeled dechloroacutumine demonstrated that acutumine is the only alkaloid metabolite of dechloroacutumine. Conversion of the exogenously applied dechloroacutumine, taken up by the roots, into acutumine showed that dechloroacutumine is the precursor of acutumine. Incomplete conversion (5%) of dechloroacutumine into acutumine suggests accumulation of the exogenously applied dechloroacutumine in cell organelles and/or compartmentation of the enzyme involved in the biosynthesis of acutumine.

In addition to acutumine, acutumidine and two new chlorine-containing alkaloids named 1-epiacutumine, and 1-epiacutumidine were isolated from *M. dauricum* root cultures and the intact plant. Their structures were determined based on MS and ^1H and ^{13}C NMR spectra. Accumulations of these alkaloids were found to be low in the intact plant compared with cultured roots.

The biosynthetic relationship among chlorine-containing alkaloids, produced by *M. dauricum* root cultures, was studied using ^{36}Cl -labeled precursors. Time course of chlorine-containing alkaloids during 60 days culture period, and feeding experiments using ^{36}Cl -labeled precursors, have clearly demonstrated that interconversions take place between acutumine and acutumidine, and between 1-epiacutumine and 1-epiacutumidine. Moreover, 1-epiacutumine was proved to be the first chlorine-containing alkaloid, which suggested that 1-epidechloro acutumine might exist as early precursor for chlorinated alkaloids produced by *M. dauricum* root cultures.

In this study, comprehension of the biosynthetic pathway of chlorine-containing alkaloids produced by *M. dauricum* was greatly improved, which allowed us to conduct the first enzymatic work on chlorination in higher plants.

Sustainable irrigation schedule using groundwater resource in Mu Us Shamo desert of China

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Expansion of irrigated agricultural land even in arid zones is demanded because of the necessity for increasing food production in view of recent rapid increase in world population. Irrigated agriculture can easily generate degradation of agricultural land because of depletion of groundwater resource and salinization. Suitable scheduling of irrigation is necessary to control this setback. The purpose of this study is establishment of sustainable irrigated agriculture using shallow groundwater resource in arid zones. Basic conception is examination of traditional irrigation method considering the saving of stock and quality of groundwater resource.

I considered about the characteristics of salinization with waterlogging and suggest the sustainable development of irrigated agriculture in inter-dune lowland (fixed and semi-fixed sand mass, damp lowland etc.) located between moving sand mass in Mu Us Shamo desert of Inner Mongolia, China. Simultaneously, I considered improvement of water application efficiency of small-strip border irrigation that is the traditional irrigation method on sandy field. Basic experiment of small-strip border irrigation was done on sandy field in Arid Land Research Center, Tottori University.

1 . The characteristics of salinization with waterlogging of soil and groundwater were investigated in inter-dune lowland, mainly about electric conductivity (EC) and pH. Salinization with waterlogging was serious around the swamp in the small lowland locating between semi-fixed sand dune and around the seasonal pond in the damp lowland located at the lowest place in the central area of inter-dune lowland. Especially the swamp soil showed large value of EC and pH in the small lowland. Groundwater flowed from sand dune to swamp in the small lowland. In the damp lowland, groundwater flowed from seasonal pond to sand dune during increase of water table of seasonal pond by rainfall, and flowed to reverse direction during successive no-rain period.

In the corn field in experimental field of Mu Us Shamo desert research center located on fixed sand land, salinization with waterlogging was not serious. Groundwater below the irrigated land flowed to southeast direction. EC of groundwater increased at downstream side affected by drainage water, especially after the fertilization.

2 . Characteristics of ion distribution of soil and groundwater of the small lowland and the corn field were considered. In the small lowland, composition of Na^+ and HCO_3^- is rich near soil surface at the swamp, and sodification is expected. In the corn field, Na^+ composition was a little and sodium adsorption ratio was low, thus danger of sodification was little.

By the characteristics of salinization, I suggested the land use to separate the slope from outside of inter dune lowland to damp lowland for groundwater catchment and agricultural land (forest, irrigated land and pasture), and calculated the area ratio of groundwater catchment for maintaining the groundwater resource. It is also important to reduce cause of salinization of groundwater, and application of efficient irrigation method small infiltration should be considered.

3 . Small-strip border irrigation that is traditional irrigation method in Mu Us Shamo desert was examined from the relationship between water application efficiency and length of border-strip to establish efficient and economic irrigation method. Runoff loss decreased with the increase of strip length, and increased with the increase of unit width inlet water discharge. Deep percolation loss increased with the increase of

strip length, and decreased with the increase of unit width inlet water discharge. Water application efficiency increased with the increase of strip length and after reaching the peak value (about 60 %) decreased gradually. Suitable length is the length of strip that showed peak value of water application efficiency. Suitable length increased with the increase of unit width inlet water discharge.

The peak values of water application efficiency of apple field and yangcai field (reforestation plant) of Mu Us shamo desert were about 60 %. Current lengths of strips of two fields were close to suitable length.

4 . Investigation of water application efficiency and length of strip of small-strip border irrigation were examined by the effect of closed-end condition and field slope. Volume balance equation that is used to analyze border irrigation was modified to add remaining water term, and water advance equation and water recession equation were modified to add slope gradient term. The result of calculation of infiltration water profile was in good agreement with measured value. By the closed-end condition, peak value of water application efficiency increased to 1.5 times, and suitable length increased to 1.13 times of open-end condition. By the sloped condition of 2.86° , length of strip increased to 1.05 times of flat condition.

In the case of applying of closed-end condition and sloped condition for apple field and yangcai field in Mu Us Shamo desert, peak value of water application efficiency increased to 1.5 times of open-end condition. Suitable length increased to 1.13 times of open-end condition for apple field, and increased to 1.15 times for yangcai field. By the sloped condition of 2.86° , length of strip increased to 1.1 times of flat condition. In the case of same strip length, water application efficiency of sloped condition of 2.86° increased 10 % compared to flat condition.

These results indicate the possibility of sustainable use of groundwater by considering of salinization condition, flow direction of groundwater and size of groundwater catchment. The length of strip of small-strip border irrigation was set to the suitable value, and improved efficiency by the effects of closed-end condition and sloped condition. From these results, traditional irrigation method considering conservation of groundwater was possible to be developed in an area with limited irrigation infrastructure in the Mu Us Shamo desert. This approach could be beneficial to other areas having similar characteristics.