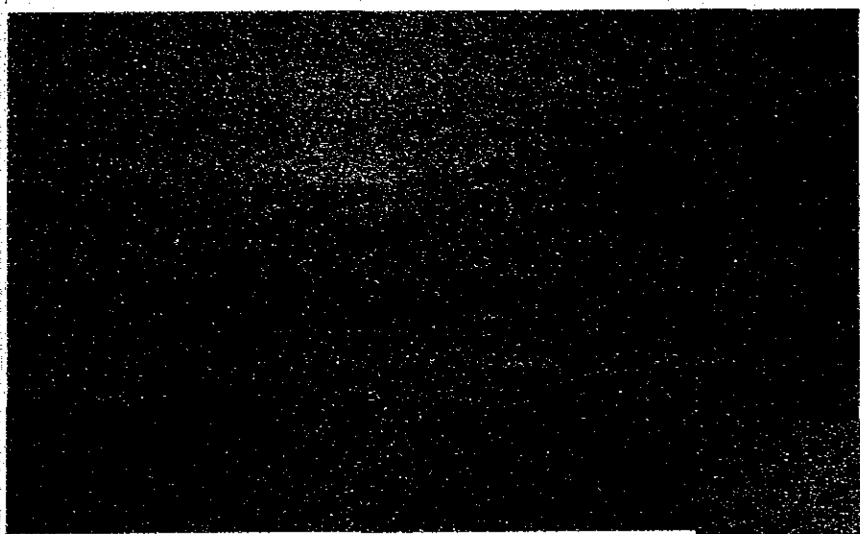
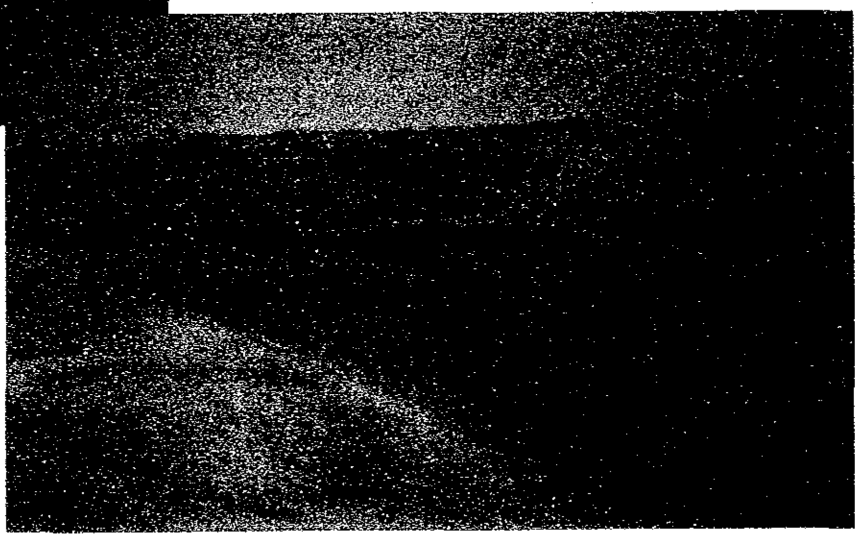
The Annual Report of the Joint Study Project on Improvement of Arid Land Agriculture in UNITED ARAB EMIRATES

(September, 1985～August, 1986)





March, 1987

The Japan International Cooperation Agency

[cover print]

Natural sand dune in west area of U.A.E.

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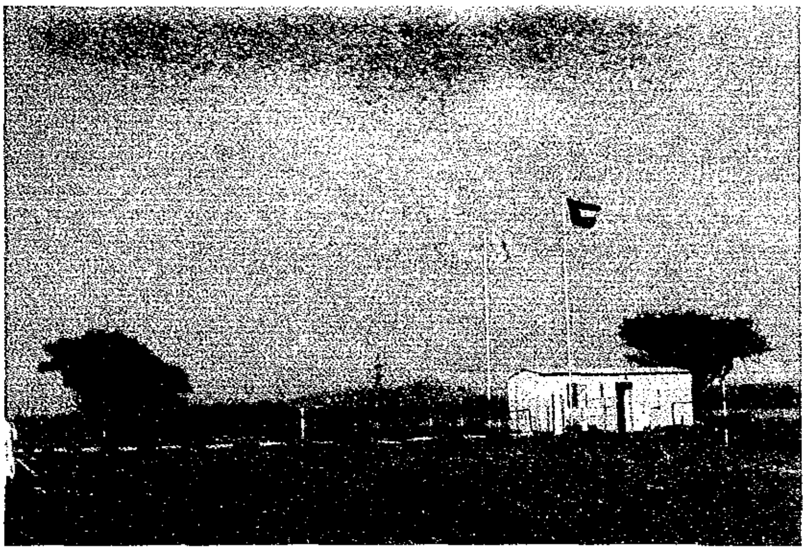
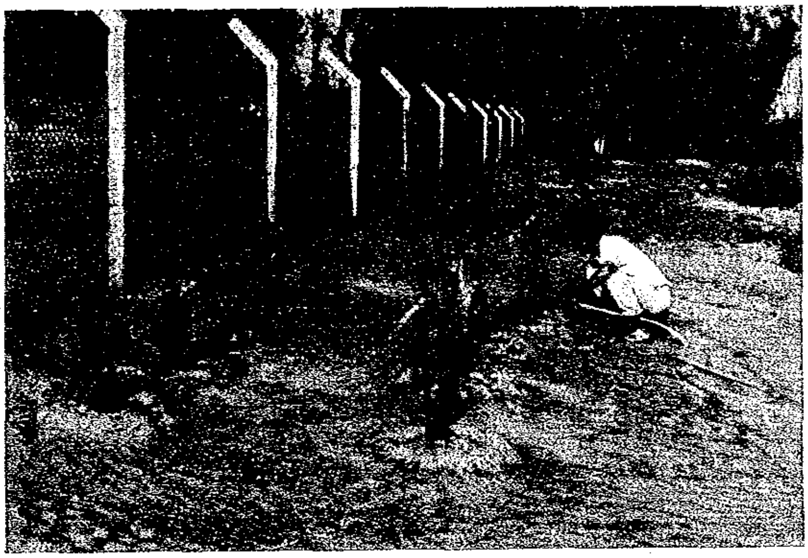
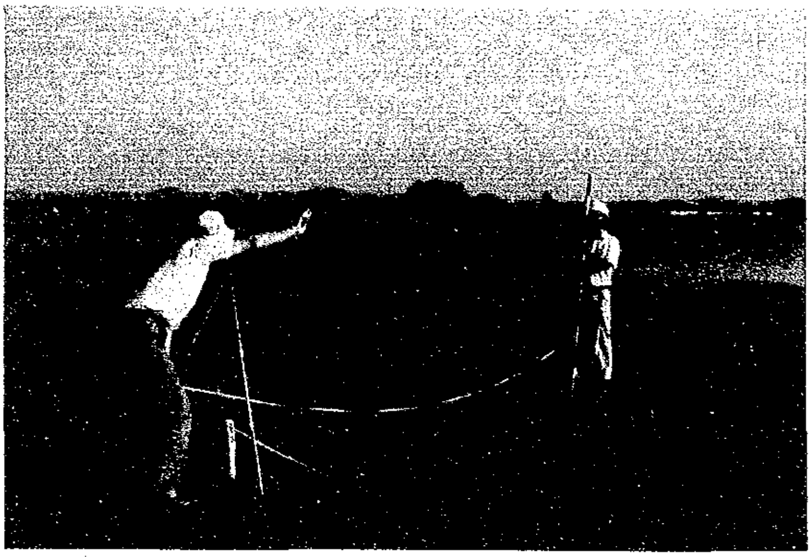


Experimental Farm, U.A.E. University. (ALOHA)



Different levels of irrigation for Samar and Ghaff trees (ALOHA). (Experiment on Theme A)

Monthly interval plantation of Samar Ghaff trees in the Experimental Farm. (Experiment on. theme A)



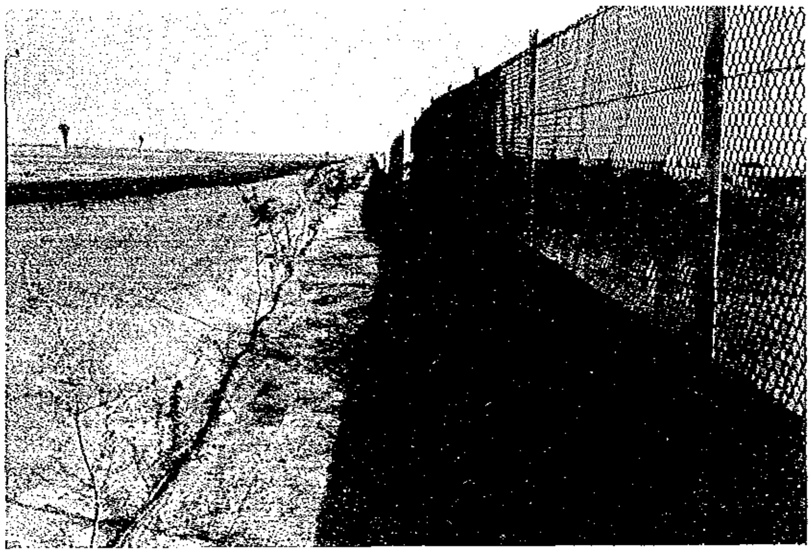
Surveying to divide the area into experimantal plots theme A.

Observation of wind speed and direction at the Experimental Farm.

Measurement of the accumulation sand at natural sand-dune in south side at the Experimental Farm.

(Experiment on theme A)

Construction of the sand fence by using Dates-fronds mat which made in U.S. E. – theme A.



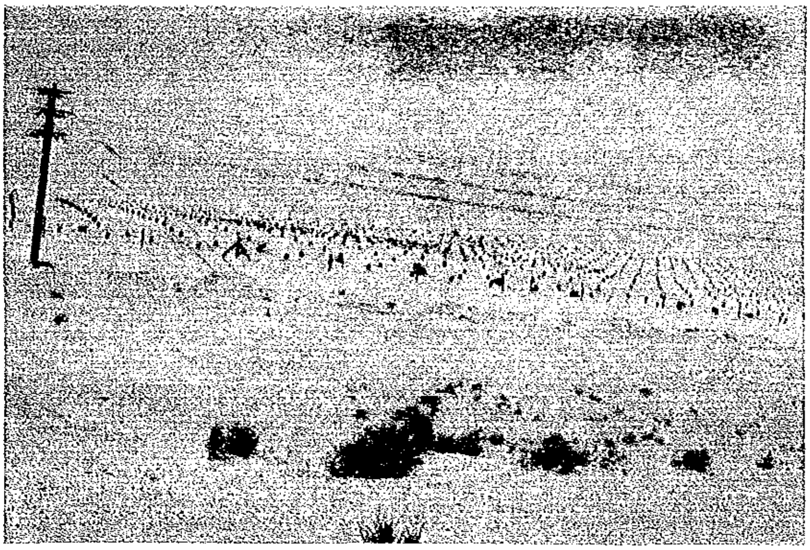
Windbreak trees planted all around fence in the Experimental Farm.

Nursery practice of Live Oak seed trees in temporary nursery for transplanting the trees in Experimental Farm (Experiment on theme A & C)

The base excavation for construction of reserviour in the Experimental Farm.

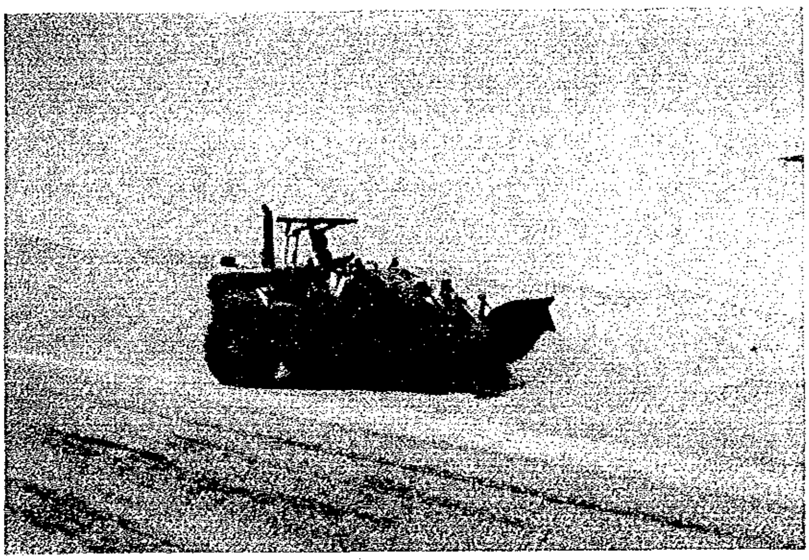
Sand-dune fixation by spraying of asphalt emulsion and tree planting (near BIDAZAID).

Observation of erosion control forest at KLKAZNA for without irrigation carried by Forest Department.

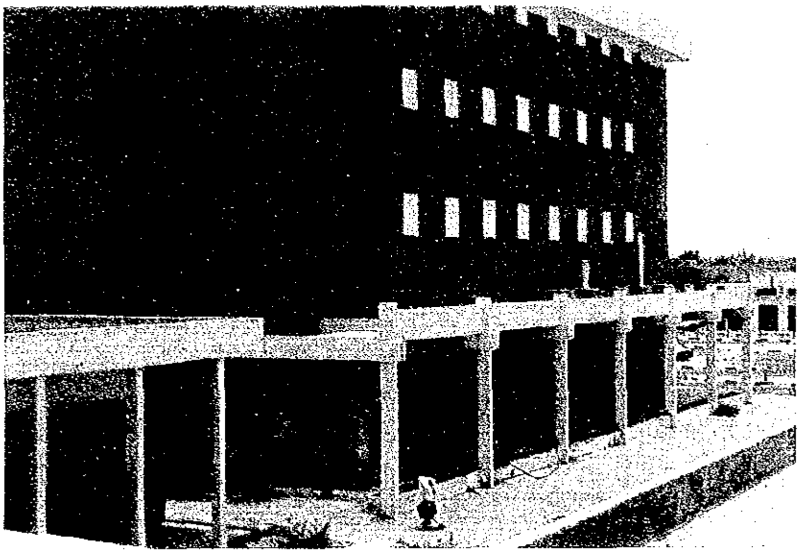


Plantation project for wind erosion control carried by ALAIN Forestry Department at ALWAGON.

Plantation of Arak tree under drip irrigation (coil drippers) at ALWAGON.

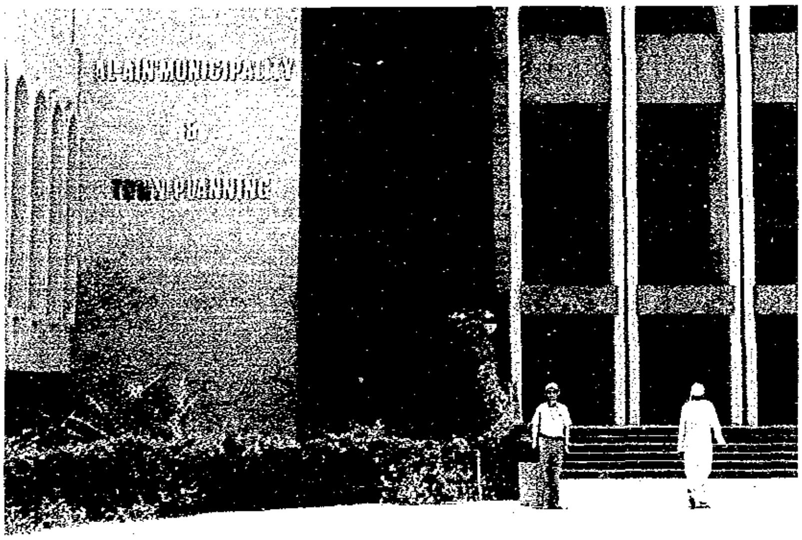


Removing the sands from asphalt roads by bulldozer.



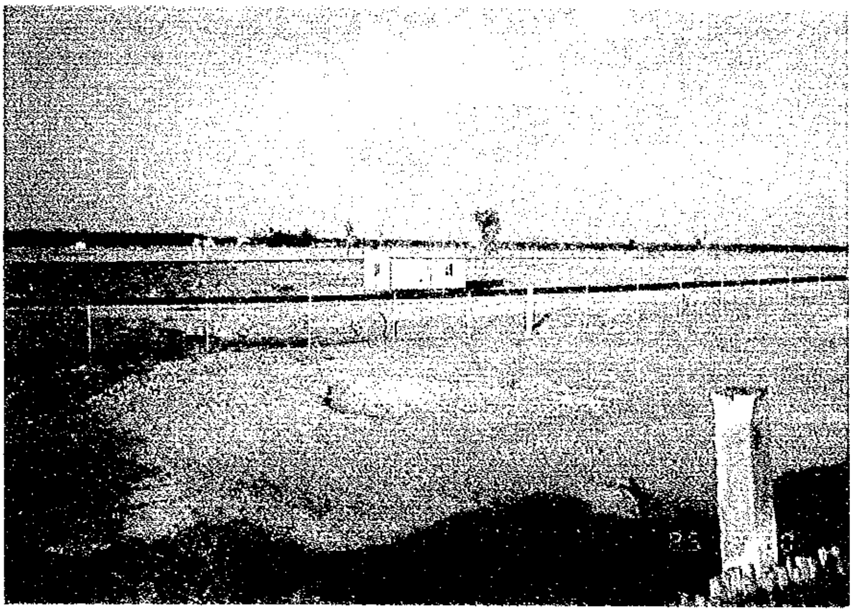
U.A.E. University Faculty of Agriculture.

Measurements of soil samples at soils and irrigation laboratory at Faculty of Agriculture, U.A.E. University.

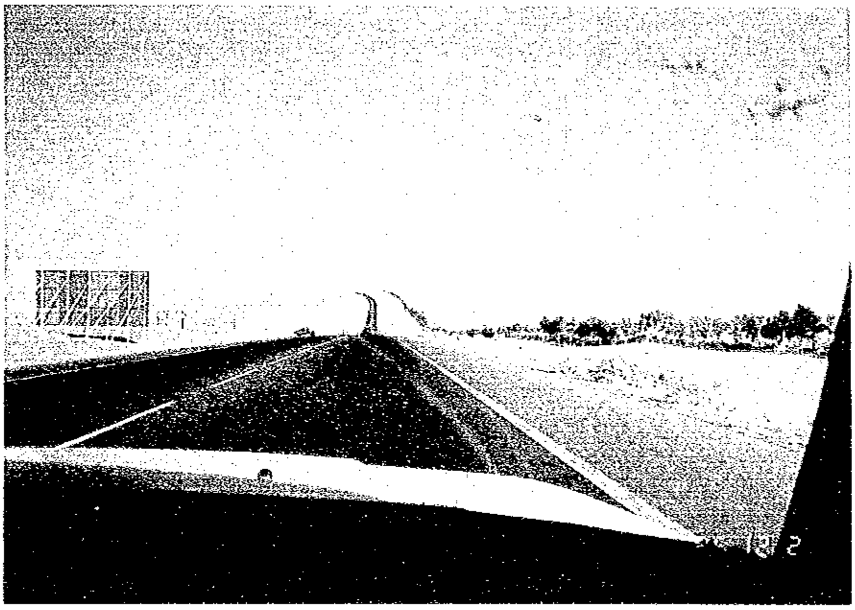


ALAIN Municipality and Town Planning.

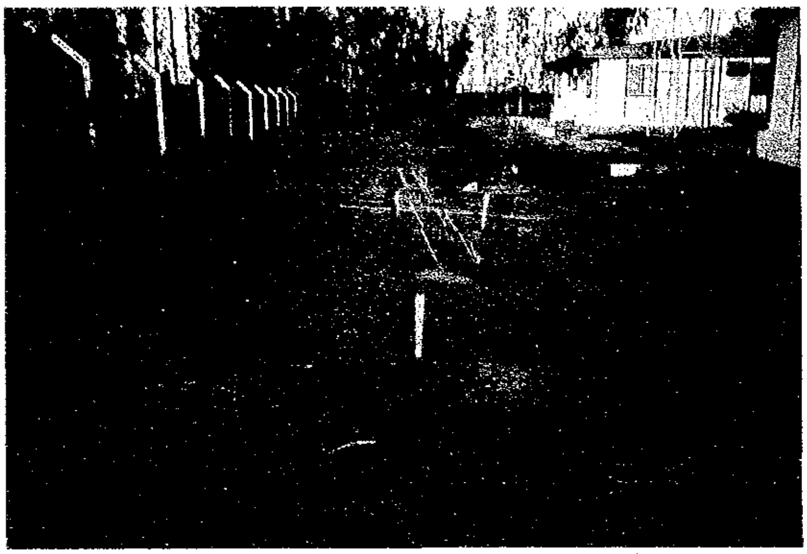
UAE University Experimental Farm seen from natural sand dune near the Farm.



Tree-planting long belt along the road between Al Ain and Dubai.

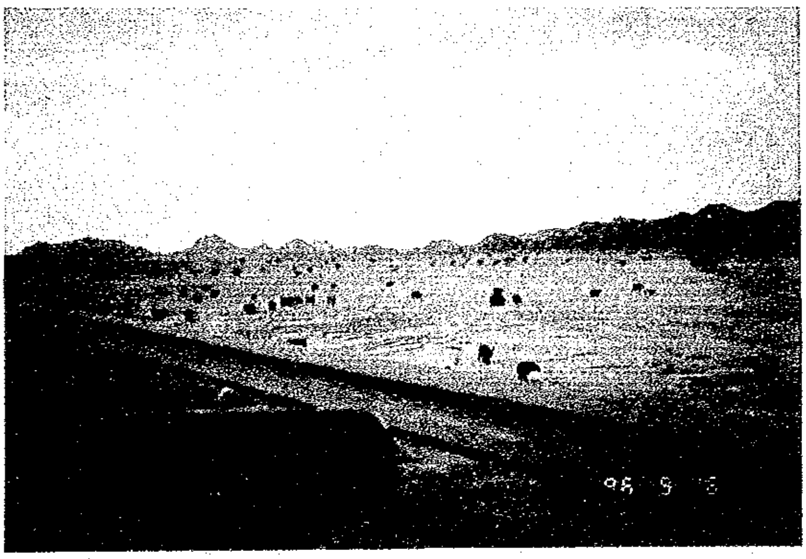


A look of crop cultivation in Buraimi oasis.

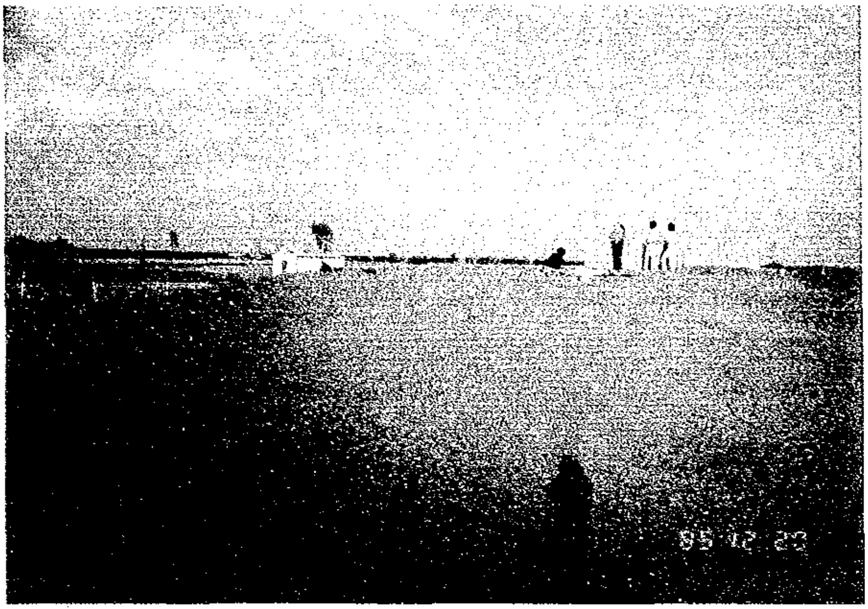


Preliminary experiments on the effect of irrigation amount on the growth of Samar and Ghaff and on the relation between soil moisture and soil temperature near the Farm.

Artificial sand dune under construction in theme A plot in the neighbourhood of the Farm.



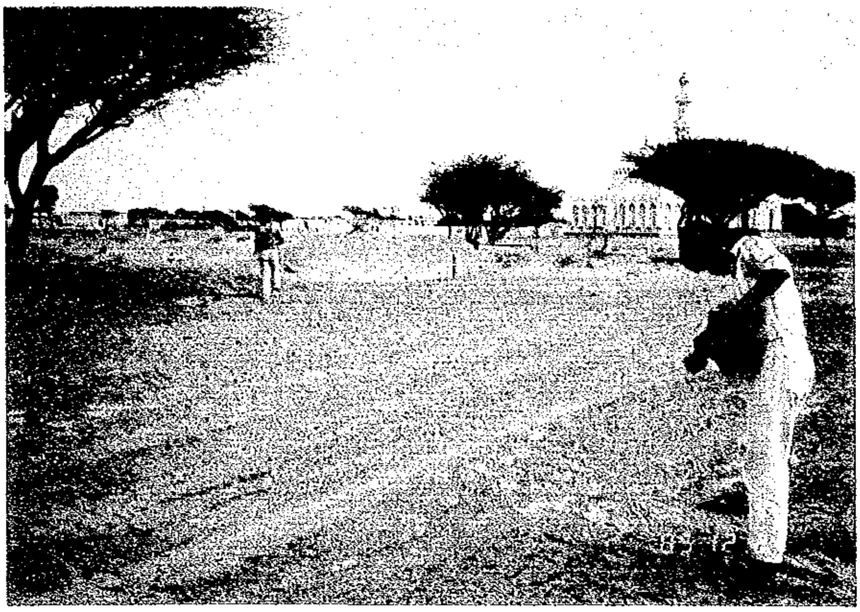
Wind-erosioned mountain and pasturage in the way from Al Ain to Oman.



The appearance of bamboo fense for experiment on the effect of bamboo fense on the movement of sand dune and wind velocity in near the Farm.

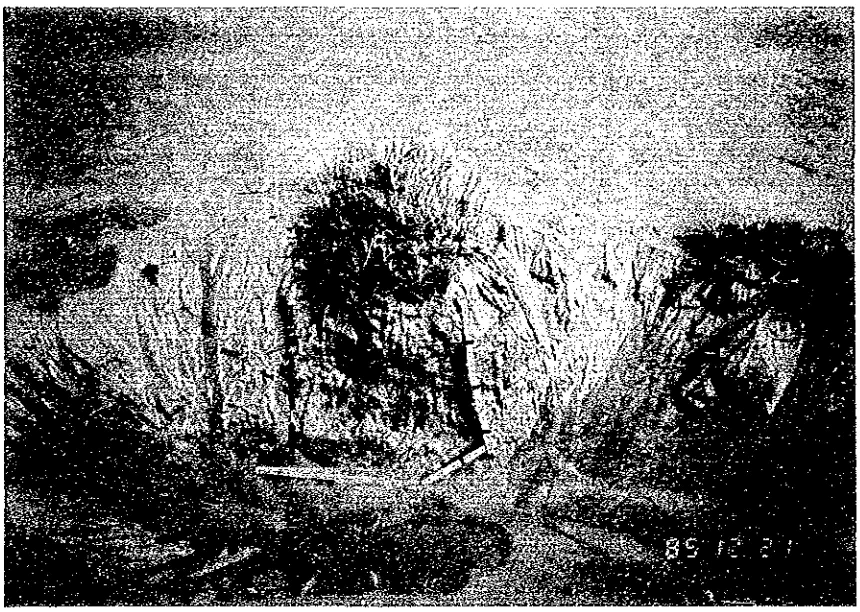
The application of bark compost for experiment on the effect of a subsurface compost layer on water preservation in a sandy soil near the Farm.

The aspect of experiment plots on the effect of a subsurface compost layer on water preservation in a sandy soil near the Farm.



The look of investigation on natural vegetation and soil in Al Oha area.

Investigation of a soil profile in Al Oha area.



Top and roots of *Cyperus conglomeratus* plant in a sand dune of Al Oha area.

CONTENTS

I. PREFACE

It is said that approximately one third of land in the whole world is occupied by the desertic arid area. Especially the greening of the arid land in countries holding the proper areas is a very important national theme which exerts an influence upon the advance in future of countries concerns.

The staff members in Faculty of Agriculture, Shizuoka University continue the endeavour for the study on arid land agriculture until now from early time, and then they had contacted with the staff in Faculty of Agriculture, UAE University on the joint study for the arid land agriculture in UAE before a few years. As the result, UAE University hoped the implementation of the joint study between both Universities under the study cooperation basis by the Japan International Cooperation Agency (JICA).

In accordance with result above, the Japanese Implementation Survey Team organized by the JICA was dispatched to UAE University on March, 1985, and discussed on the joint study. As a result of discussions, the team mentioned above and UAE University agreed to implement the Joint Study Project on Improvement of Arid Land Agriculture in UAE during September, 1985 to March, 1989, and concluded the record of discussion (R/D).

Two long-term experts from JICA were dispatched to UAE University on August, 1985 according to the R/D, and they implemented the preparation for experiments and investigated cultivation method of crops in Al Ain and afforestation areas in Abu Dhabi Emirate. On September, 1985 and June, 1986, three and one short-term experts were respectively dispatched to UAE University, and the draft plans for implementation of the Joint Study Project were discussed between both UAE University and Shizuoka University teams. And then the study framework mentioned as below had been decided by the teams.

The implementation phase in the first year of the Project is described, and the major papers of preliminary survey and experiments by the Project teams also included in this annual report.

The constructions such as leveling, artificial sand dune and irrigation system for field plots of the Project in the University Experimental Farm were delayed about one year in comparison with the prearrangement of the Project. But the facilities mentioned above are expected to be established by the endeavour of UAE University by the end of October, 1986. Accordingly the real experiments will be started from the second year of the Project.

II. MASTER PLAN OF THE JOINT STUDY PROJECT

1. Background

The high temperature, drought, scare rainfall, strong wind, drifting sand, movement of sand dune and high salinity of the soil, of which peculiarities are common to almost all arid lands, are obstructing the agricultural production. It is essential to improve and develop the agriculture in the United Arab Emirates by overcoming the aforesaid meteorologic and environmental conditions through the research.

2. Objectives

The joint study project is aimed at improvement and development of agriculture in the arid lands through basic researches in the main theme "Studies on the development of agriculture by fixation of sand dune and production of crops under saved water and saline water irrigation in the United Arab Emirates". It is expected, in consequence, that the proposed researches and experiments between two Universities would make positive contributions to the international cooperation and development in the field of agriculture in arid lands.

3. Study Framework

(1) Scope of Study

The project will cover the following study items:

Theme A: Studies on sand dune fixation by methods of revegetation work with civil engineering

Theme B: Studies on the improvement of cultivation methods for crop production under irrigation of saline water

Theme C: Studies on introduction and breeding of well-known drought- and salt-tolerant crops in UAE

The outline of the Joint Study Plot is shown in Fig. 1.

(2) Outline of Each Theme

Thme A: Studies on sand dune fixation by methods of revegetation work with civil engineering

This theme is consisted of four major works. First work is construction of artificial sand dune. Second work is construction of sand fences in different density. Third work is tree planting of some local trees, such as *Acacia tortilis* (Samar) and *Prosopis spicigera* (Ghaff). And fourth work is mulching treatment by some chemical mulching materials. The outline of experimental plot is shown in Fig. 2. and time schedule is shown in Table 1.

The effects of each treatment should be evaluated by wind velocity, amount of shifting sand, topographic change of experimental area, water contents in sand, and growth condition of planting trees.

In this theme, some other observation works also have been conducted, such as collection of fundamental data (wind direction, wind velocity and amount of shifting sand at non-treatment area), investigation of afforestation area or sand-dune fixation project and irrigation of natural vegetation in UAE.

Theme B: Studies on the improvement of cultivation methods for crop production under irrigation of saline water

Theme B–1: Studies on the effects of a subsurface compost layer on water preservation, salinity and yields of crops in sandy soil

Saving water and preventing salt accumulation are very important subjects to develop the arid land agriculture successfully.

Several kinds of compost will be used to achieve above items. In this theme, comparison of irrigation tubes and introduction of some water-holding materials will also be discussed. Wheat, alfalfa and other important vegetables will be cultivated.

This study is consisted of two major parts as follows:

(1) The effects of a subsurface bark compost layer on water preservation, salinity and crop yields under irrigation of saline water in sady soil

(2) The residual effects of subsurface layers of composts from herbaceous and arboreous plants on the growth of crop plants

Following items will be measured:

a. moisture, nutrients and salinity in soil
b. plant yield
c. nutrients in plant

Theme B–2: Studies on cultivation methods in UAE

The major objective of this study is to improve the cultivation method in arid land. First of all, the conventional cultivation method of wheat, alfalfa and other important crops in UAE should be investigated in order to determine the sandard cultivation method in this experiment. This study is consisted of two major parts as follows:

(1) Studies on growth analysis of crops

Following items will be investigated in this study

a. dry master weight of plant
b. leaf area
c. transpiration and photosynthesis of plant

According above results, growth analysis will be done in order to investigate plant growth under the arid condition by calculation of leaf area index(LAI), net assimilation rate(NAR) and relative growth rate(RGR).

(2) Effect of cultivation methods on soil temperature, soil moiture and plant growth

Several kinds of treatment mentioned as below will also be discussed in this study.

a. irrigation methods and irrigation amount
b. mulching
c. shading

Following items will be measured in this study.

a. air temperature and canopy relative humidity
b. soil temperature and soil moisture
c. plant growth and plant yield

The time schedule of these studies are also shown in Table 1, and the outline of theme B plot is shown in Fig. 3.

Theme C: Studies on introduction and breeding of well-known drought- and salt-tolerant crops in UAE

There are lots of problems against the agricultural development in arid land. And the most serious problems of them are water shortage and salt accumulation. This study is conducted in order to overcome these problems by introducing drought-tolerant and salt-tolerant crops.

This theme is consisted of two parts.

Part I: Short-term objective: Introduction of well-known drought- and salt-tolerant crops mentioned as follows:

a. Forage crops and grasses
b. Cereal crops
c. Vegetables
d. Trees and shrubs

Part II: Long-term objective: Studies for collection of different crops and varieties on drought- and salt-tolerance

a. collection of conventional drought- and salt-tolerant genes
b. collection of wild drought- and salt-tolerant genes
c. investigation and selection of theses genes
d. breeding of new varieties

The part II of this theme will mainly be conducted by UAE University side, and Japanese side will cooperate to them.

The outline of theme C plot is shown in Fig. 3.

4. Project Team

The project will be implemented jointly by the Japanese Team and the United Arab Emirates University Study Team. Each team will consist of the following experts:

(1) THE UAE STUDY TEAM

Dr. Nizar HAMADMAD, Team Leader, Dean
Dr. Mahmoud A. AlAFIFI, Chairman of crop production (Soil Science)
Dr. Abuel Hassan S. IBRAHIM, Agronomy
Dr. Ahmed A. HASSAN, Horticulture
Dr. Ahmed A. ALMASOUM, Horiculture
Mr. Suhayl A. ITANI, Soil & Irrigation

(2) THE JAPANESE STUDY TEAM

Dr. Keiichiro MATSUDA, Team Leader, Soil Science
Dr. Mamoru NAGAI, Crop Science
Dr. Hiroshi MURAI, Forest Hydrology
Dr. Hitoshi SAWADA, Crop Science
Mr. Yasuo YUASA, Sirviculture
Mr. Hiromi YOKOTA, Plant Nutrition
Mr. Akira KOTO, Soil Science

5. Project Phases

(1) Phase 1 (Sept. 1985–Aug. 1986)
(2) Phase 2 (Sept. 1986–Aug. 1987)
(3) Phase 3 (Sept. 1987–Aug. 1988)
(4) Phase 4 (Sept. 1988–Mar. 1989)

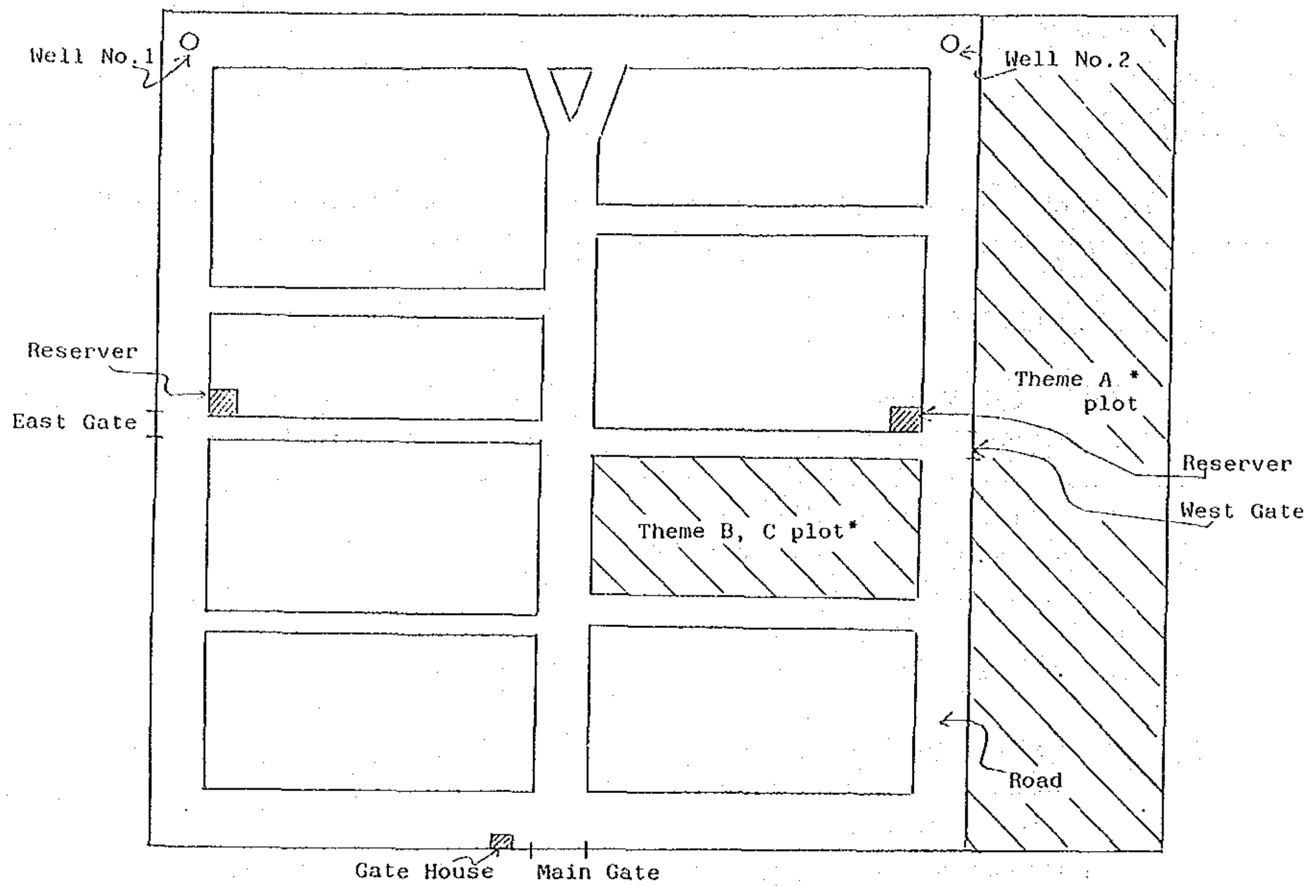


Fig. 1. Outline of the University Experimental Farm in 1986
* Plot for the Joint Study Project

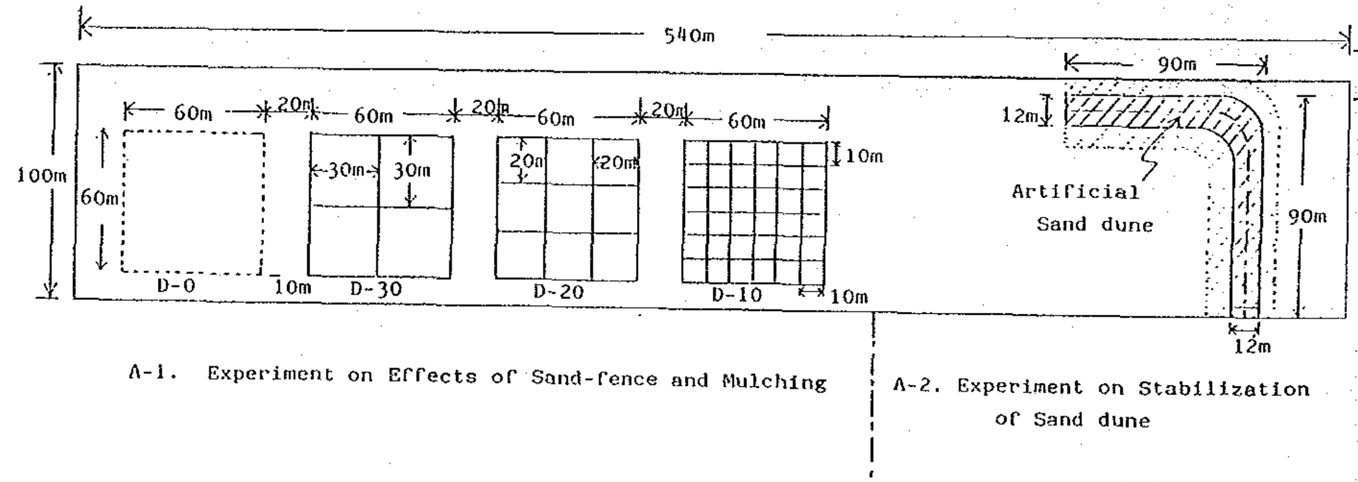


Fig. 2. Design of experimental plot on theme A

Table 1. Time schedule of thema A, B and C

	Phase 1 (Sept. 1985 — Aug. 1986)	Phase 2 (Sept. 1986 — Aug. 1987)	Phase 3 (Sept. 1987 — Aug. 1988)	Phase 4 (Sept. 1988 — Mar. 1989)
Theme A	∘ construction of artificial sand dune ∘ leveling, filling the hole ∘ construction of irrigation system			
		∘ construction of sand fence ∘ mulching treatment ∘ tree planting		
		∘ observation of wind velocity, shifting sand and tree growth		
	∘ investigation of other afforestation areas and sand dune fixation projects in UAE			
Theme B	∘ leveling ∘ construction of irrigation system			
	∘ investigation of cultivation methods in UAE	∘ cultivation experiments		
Theme C	∘ leveling ∘ construction of irrigation system			
	∘ collection of seeds			
		∘ preliminary experiments	∘ cultivation experiments	

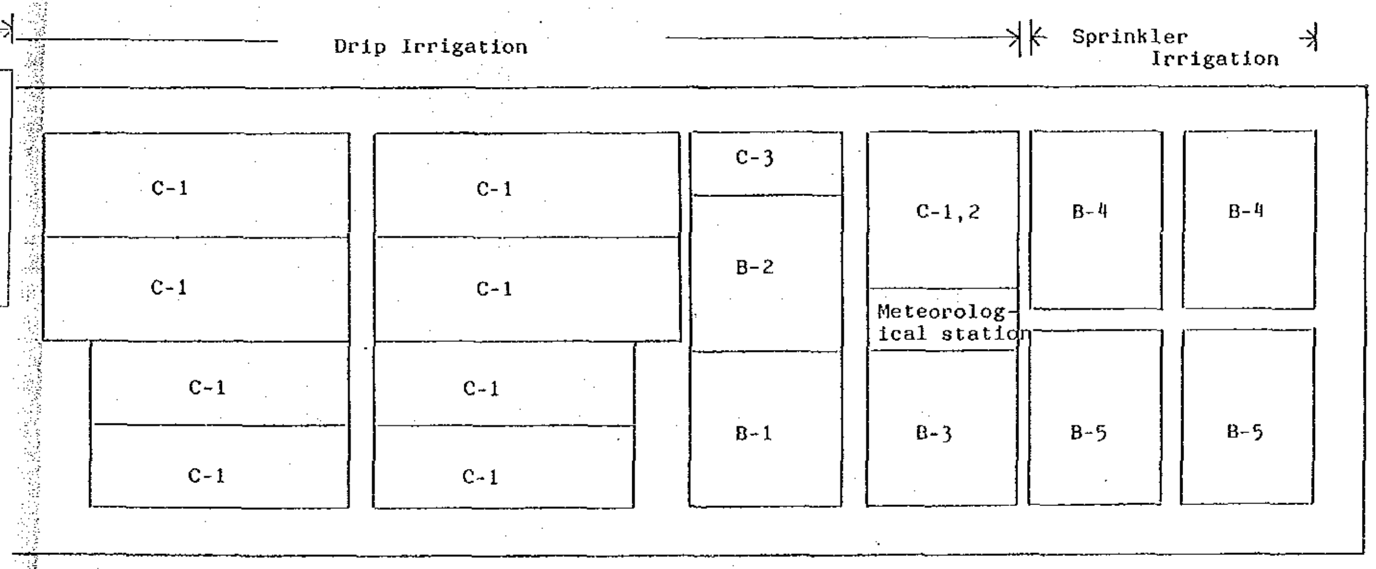


Fig. 3. Design of experimental plot on theme B and C

III. PROGRESS OF CONSTRUCTION WORKS IN THE UNIVERSITY EXPERIMENTAL FARM

1. Internal road

This work was finished in January, 1986. The internal road was constructed and pave(as Fig. 1.

2. Planting of Wind Break Trees

Wind break trees were transplanted during from April 17, 1986 to May 25, 1986. Tw(kinds of trees, *Tamalix articulata* and *Inga edvlis* (Ghaff bahar), were planted.

3. Construction works of the Joint Study Project Plot

(1) The plot of theme A

The artificial sand dune have been constructed, but leveling of the plot is not still com pleted as shown in Fig. 4 in early part of September 1986. Irrigation system for the plot will b(constructed after the completion of leveling.

(2) Plots of theme B and C

The reserver tanks for irrigation is still constructing in early part of September, 1986. Leveling and irrigation system of the plots will be arranged after the completion of reserver tanks.

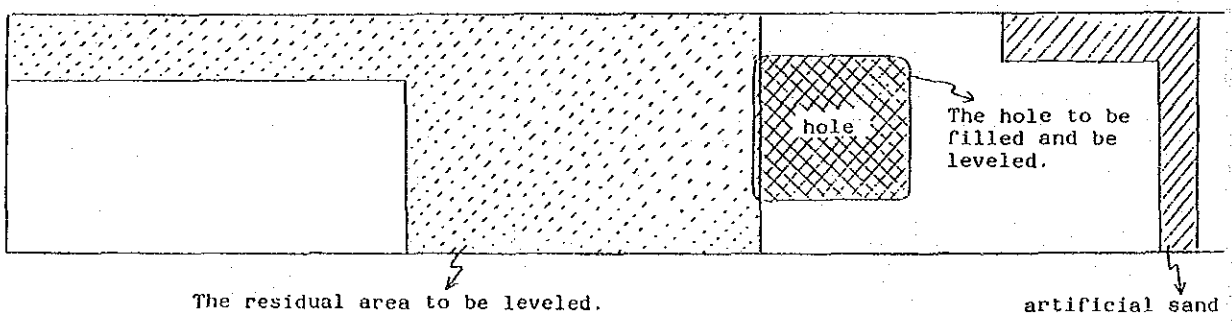


Fig. 4. Outline of theme A plot in early part of September, 1986

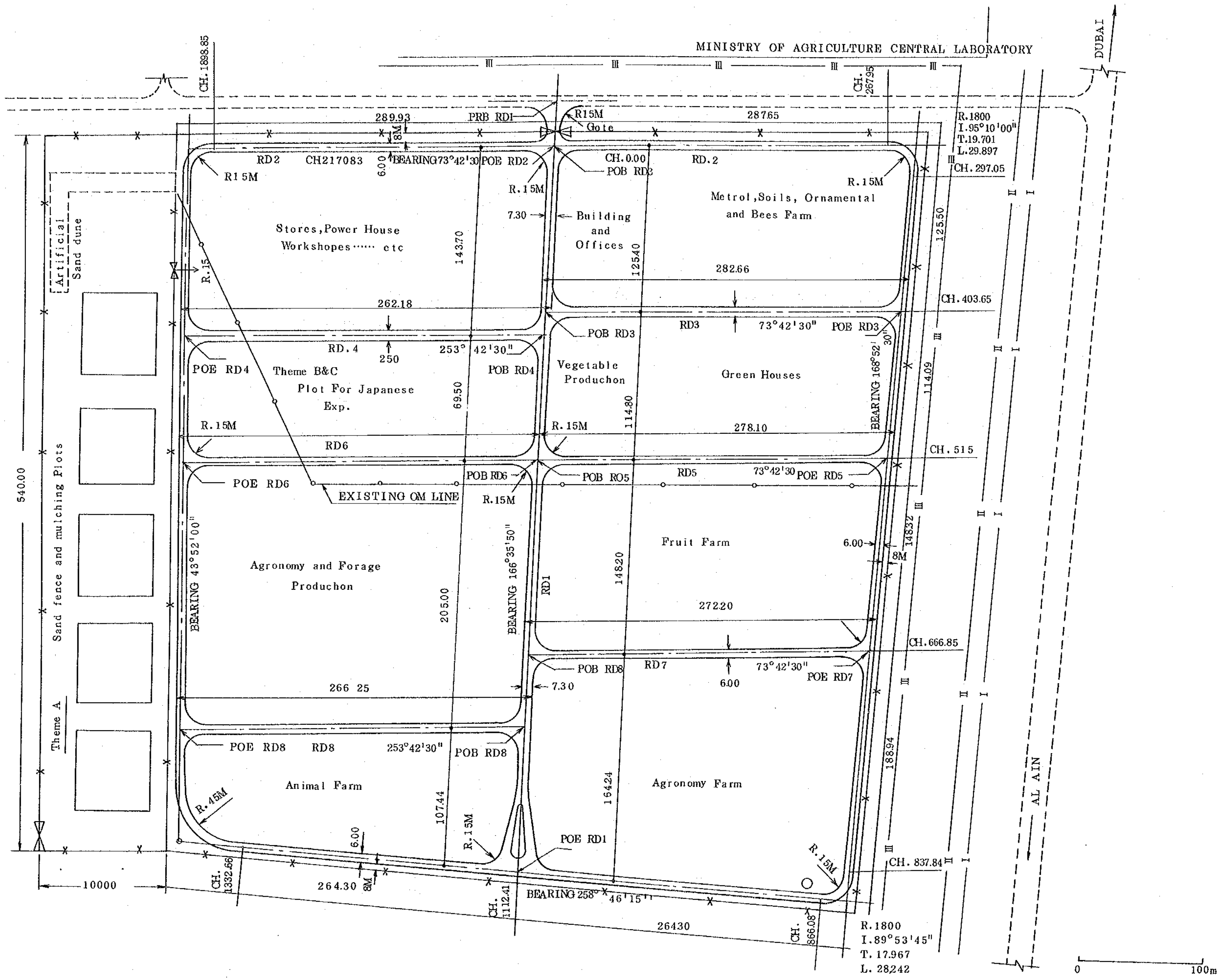


Fig. III-1 University Experimental Farm

IV. PRELIMINARY SURVEY AND EXPERIMENT

1. Effect of sand fence on sand dune movement and wind velocity in natural sand dune area (Theme A)

Sand movement is a common natural phenomenon in the desert region. Sand in the region is blown away by wind, and shifting sand invades or buries residence area, road and farm. So it is very important to prevent the shifting sand.

This study was carried out in order to investigate the effect of bamboo fence on the sand movement and wind velocity.

1–1. Experiment 1: The effect of bamboo fence on sand dune movement

Abstract

This experiment was carried out in order to investigate the effects of bamboo fence on sand movement. The sand movement was measured as the height change at the ground surface using measuring piles.

The following results were obtained:

(1) The bamboo fence is effective to prevent the sand dune movement. The top of sand dune of control plot moved 3 m from south to north after 12 weeks of treatment. On the contrary, the formation of sand dune in bamboo fence plot did not change so apparently.

(2) The preventive ratio for shifting sand by the bamboo fence was approximately 76%.

(3) The measured maximum advance velocity of sand dune in control plot was approximately 2m/month during this experiment.

Materials and Methods

This study was conducted at the natural sand dune area neighbouring the University Farm in Al Oha. Bamboo fence was established at the top of the sand dune on 20, Dec., 1985, and surveying piles were driven into each plot on 30, December, 1985 (See Fig. 5). The bamboo fence was 1 m in height, and the dencity (opening ratio) of the bamboo fence was approximately 50%. Exposed length from ground surface of each pile was measured weekly. The height of each measurement point was measured by ordinary surveying method using automatic level (TOPCON AT-F2) and object stuff. From these data, cross section figure of each plot was drawn.

The amount of shifting sand in each measurement square was calculated by the changes of exposed pile lengths. The equation is mentioned as below:

$$Q = \frac{a+b+c+d}{4} \times \frac{1}{100} \times 2 \times 2 \qquad (1)$$

Q: amount of shifting sand (m^3)

a, b, c, d: changes in exposed lengths of four pile (cm)

The measurement was started on 5, Janaury, 1986, and was continued for 12 weeks.

Results and Discussion

The change of exposed length of each pile is shown in Table 2–1 to 2–3. Each figure is the average of five measurement points. Cross section figures of each plot are shown in Fig. 6. From Fig. 6, it is found that sand moved from north to south during first 4 weeks and then moved from south to north. It shows that predominant wind direction was north during first 4 weeks, then changed to south. (Wind direction and velocity meter was established in the University Farm on 6, March, 1986. Wind data at the University Farm is not available before that date). And the top of the sand dune in control plot moved approximately 1m, 2m and 2m after 4 weeks, 8 weeks and 12 weeks of experiment, respectively. Therefore, the maximum advance velocity of sand dune in control plot was approximately 2m per month during this experiment. And in a result, the top of sand dune in control plot moved 3m from south to north in 12 weeks. On the other hand, the formation of sand dune did not change so apparently in bamboo fence plot (See Fig. 6). So it is clear that the bamboo fence is effective to prevent the sand dune movement.

The amount of shifting sand in each plot is shown in Table 3. Each figure is the total of four measurement squares. In control plot, the accumulated amount of shifting sand in the measurement plot was 7.74, 22.08 and 21.61m^3 after 4 weeks, 8 weeks and 12 weeks of experiment, respectively. On the other hand, in bamboo fence plot, the accumulated amount of shifting sand in the measureing plot was 1.80, 3.76 and 7.04m^3 after 4 weeks, 8 weeks and 12 weeks of experiment, respectively. It shows that the shifting sand is reduced to approximately 1/3–1/6 by the bamboo fence. In order to comprehend the effect of bamboo fence on the amount of shifting sand numerically, the preventive ratio of shifting sand was also calculated. This ratio was calculated by equation (2):

$$P = \frac{C-F}{C} \times 100 \qquad (2)$$

P : preventive ratio of shifting sand (%)

C : accumulated amount of shifting sand in control plot (m^3)

F : accumulated amount of shifting sand in bamboo fence plot (m^3)

This ratio is shown in Table 4. Table 4 shows that approximately 76% of shifting sand was prevented by the bamboo fence during this 12 weeks experiment.

1–2. Experiment 2. The effect of bamboo fence on wind velocity

Abstract

The effect of bamboo fence on wind velocity and the relationship between wind velocity

and the accumulated amount of shifting sand were studied in the natural sand dune area. Wind velocity was measured by portable anemometer, and the accumulated amount of shifting sand was calculated from the hight change of the ground surface measured by surveying piles.

The following results were obtained:

(1) On the leeward side, wind velocity in bamboo fence plot was greatly reduced by the bamboo fence in contrast with control plot.
(2) The calculated minimum wind velocity causing sand movement (Umin) was 4.4 m/sec.
(3) In bamboo fence plot, wind velocity on the leeward side was reduced to less than Umin, and it resulted in the prevention of sand dune movement.

Materials and Methods

This study was conducted at the same area as Experiment 1 (See Fig. 5).

Wind velocity and wind direction were measured by portable anemometer (OHTA KEIKI, No.24) at the hight of 1m from ground surface. The standard wind velocity (U) was measured at the top of sand dune in control polot, and at the same time, wind velocity at the slope of sand dune (Uslope) was also measured in each plot. The distance from the top of sand dune (or the bamboo fence) to each measuring point was 1, 2, 4, 6, 8 and 10m (See Fig. 7). Wind velocity was measured at least three times at each measuring point, and the average wind velocity was calculated at each measuring point. The relative wind velocity (the ratio of Uslope to U) was also calculated at each measuring point in order to determine the effect of the bamboo fence on wind velocity.

The accumulated amount of shifting sand was calculated from the change in exposed pile length.

The measurement was carried out from the late of March, 1986 to the beginning of April, 1986.

Results and Discussion

The relative wind velocity, the average wind velocity and wind direction in each plot are shown in Table 5. Because wind velocity varied from 0 m/sec to 11.6 m/sec during this experiment, the data were classified in two classes, namely one was moderate wind (from 5.5 to 7.9 m/sec) and the other was strong wind (from 8.0 to 11.6 m/sec). And the class of gentle wind (less than 4.0 m/sec) was eliminated from Table 5, becuase wind direction was variable when wind velocity was low. Wind direction was almost south (from SSE to SSW), and was almost vertical against the bamboo fence during these measurements.

The relative wind velocity curve was also drawn (Fig. 8). It is clear that wind velocity is greatly reduced by the bamboo fence. And it is reflected on the accumulated amount of shifting sand. (Even in control plot, the relative wind velocity is also reduced according to an increasing in the distance from the top of sand dune. It is topographic effect of sand dune.)

The relationship between average wind velocity and the accumulated amount of shifting sand is shown in Table 6. In general, the windward slope of sand dune is erosion (decreasing) side, and the leeward slope of sand dune is deposition (increasing) side (See Fig. 9).

In this paper, the accumulated amount of shifting sand is represented by TIS2H (Tota Increasing Amount of Shifting Sand), TIS2H shows the total increasing amount of shifting sand i the leeward measurement area for two hours. It is clear that sand movement was prevented by th bamboo fence as reported in Experiment 1.

Linear regression analysis method was used in the relationship between wind velocity an TIS2H in order to get the minimum wind velocity causing sand movement (Umin) in control plo The result is shown in Table 7. From the result of linear regression analysis. Umin is estimated at 4. m/sec. According to Table 7, average wind velocity in the bamboo fence plot is less than Umin a every measuring point. In contrast, average wind velocity in control plot is more than Umin at mo of measuring points. This is the major reason that sand movement was prevented by the bambo fence.

The measuring data of wind velocity and amount of shifting sand are shown in Table 8–1 8–2, 8–3, 8–4, 8–5, 8–6, 9–1, 9–2 and 9–3.

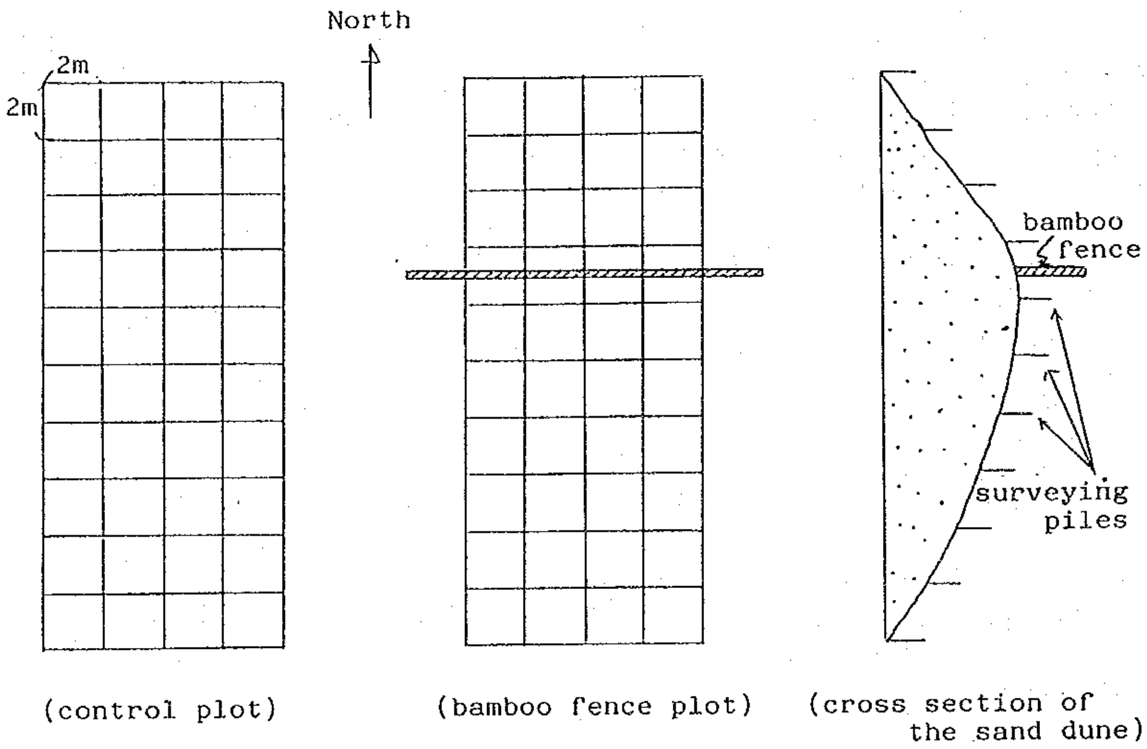


Fig. 5. **Outline of experimental Plots**

Table 2-1. The change of exposed pile length (1)

Treatment	Distance (m)	After 1 week a*1	After 1 week b*2	After 2 weeks a	After 2 weeks b	After 3 weeks a	After 3 weeks b	After 4 weeks a	After 4 weeks b
control	7	+0.1	+0.1	-1.4	-1.3	+0.1	-1.2	+1.0	-0.2
	5	-0.3	-0.3	+0.7	+0.4	+0.8	+1.2	-3.7	-2.5
	3	-4.1	-4.1	+1.4	-2.7	+0.2	-2.5	-11.7	-14.2
	1	-8.1	-8.1	+1.8	-6.3	-0.8	-7.1	-9.1	-16.2
	0	-4.9	-4.9	+1.6	-3.3	-1.8	-5.1	-6.5	-11.6
	1	+1.8	+1.8	+1.9	+3.7	-1.9	+1.8	-0.8	+1.0
	3	+16.4	+16.4	-5.3	+11.1	+2.2	+13.3	+15.4	+28.7
	5	+6.1	+6.1	-4.5	+1.6	+1.6	+3.2	+14.5	+17.7
	7	-0.3	-0.3	-2.1	-2.4	-0.8	-3.2	+5.4	+2.2
	9	+0.1	+0.1	-2.4	-2.3	-1.2	-3.5	-1.1	-4.6
	11	-0.7	-0.7	-1.1	-1.8	-1.0	-2.8	-0.6	-3.4
	13	+0.1	+0.1	-1.1	-1.0	-0.7	-1.7	-0.7	-2.4
bamboo fence	7	-0.7	-0.7	-2.0	-2.7	-0.5	-3.2	-1.2	-4.4
	5	-0.5	-0.5	-1.3	-1.8	-0.6	-2.4	+0.3	-2.1
	3	-0.6	-0.6	+0.6	±0	+0.3	+0.3	-0.8	-0.5
	1	-1.6	-1.6	+0.2	-1.4	-0.4	-1.8	-12.8	-14.6
	0	-4.0	-4.0	-6.0	-10.0	-5.0	-15.0	-0.2	-15.2
	1	+1.3	+1.3	-2.8	-1.5	+0.5	-1.0	+12.6	+11.6
	3	+0.2	+0.2	-1.3	-1.1	-0.5	-1.6	+8.1	+6.5
	5	+0.7	+0.7	-1.7	-1.0	-0.8	-1.8	+1.5	-0.3
	7	+0.5	+0.5	-1.5	-1.0	-1.0	-2.0	+2.3	+0.3
	9	+0.6	+0.6	-1.8	-1.2	-1.2	-2.4	+0.1	-2.3
	11	+0.2	+0.2	-2.1	-1.9	-0.6	-2.5	+0.5	-2.0
	13	±0	±0	-0.6	-0.6	-0.5	-1.1	+1.9	+0.8

*1 average change in height of measuring piles (cm)

*2 cumulative change in height of measuring piles (cm)

Table 2-2. The change of exposed pile length (2)

Treatment	Distance (m)	After 5 weeks a[*1]	b[*2]	After 6 weeks a	b	After 7 weeks a	b	After 8 weeks a	b
control	7	+2.5	+2.3	+4.1	+6.4	+8.4	+14.8	+1.2	+16.0
	5	+4.8	+2.3	+7.7	+10.0	+13.0	+23.0	+4.7	+27.7
	3	+6.6	-7.6	+29.2	+21.6	+31.2	+52.8	-3.2	+49.6
	1	+10.7	-5.5	+27.3	+21.8	-0.6	+21.2	+1.0	+22.2
	0	+9.3	-2.3	+7.1	+4.8	-4.8	±0	+4.2	+4.2
	1	+4.5	+5.5	-10.7	-5.2	-7.6	-12.8	+1.0	-11.8
	3	-10.6	+18.1	-22.8	-4.7	-15.9	-20.6	-2.2	-22.8
	5	-9.1	+8.6	-11.4	-2.8	-14.5	-17.3	-3.4	-20.7
	7	-1.8	+0.4	-6.4	-6.0	-9.3	-15.3	-2.4	-17.7
	9	-0.8	-5.4	-1.5	-6.9	-4.8	-11.7	-1.8	-13.5
	11	-0.7	-4.1	-0.9	-5.0	-1.8	-6.8	-1.1	-7.9
	13	-0.1	-2.5	-0.5	-3.0	-0.6	-3.6	-0.5	-4.1
bamboo fence	7	-0.1	-4.5	+1.3	-3.2	-0.1	-3.3	-0.2	-3.5
	5	-0.1	-2.2	+1.0	-1.2	+1.8	+0.6	+0.9	+1.5
	3	+2.3	+1.8	+7.7	+9.5	+15.0	+24.5	-0.5	+24.0
	1	+2.3	-12.3	-2.3	-14.6	-8.5	-23.1	+1.9	-21.2
	0	-9.5	-24.7	-4.2	-26.9	-5.5	-32.4	-7.2	-39.6
	1	-3.7	+7.9	-7.1	+0.8	-11.1	-10.3	-5.4	-15.7
	3	-2.7	+3.8	-7.8	-4.0	-9.1	-13.1	-3.5	-16.6
	5	-0.7	-1.0	-3.0	-4.0	-6.4	-10.4	-0.6	-11.0
	7	-1.3	-1.0	-3.2	-4.2	-5.3	-9.5	-1.7	-11.2
	9	-1.2	-3.5	-1.2	-4.7	-2.8	-7.5	-1.1	-8.6
	11	+0.3	-1.7	-1.0	-2.7	+0.1	-2.6	+0.2	-2.4
	13	-1.2	-0.4	±0	-0.4	+0.8	+0.4	+0.6	+1.0

*1 average change in height of measuring piles (cm)

*2 cumulative change in height of measuring piles (cm)

Table 2-3. The change of exposed pile length (3)

Treatment	Distance (m)	After 9 weeks a[*1]	b[*2]	After 10 weeks a	b	After 11 weeks a	b	After 12 weeks a	b
control	7	+4.1	+20.1	+41.5	+61.6	+14.0	+75.6	-0.4	+75.2
	5	+13.8	+41.5	+47.5	+89.0	+26.9	+115.9	-12.3	+103.6
	3	+9.5	+59.1	+13.3	+72.4	+5.8	+78.2	-3.5	+74.7
	1	-6.6	+15.6	-14.5	+1.1	-4.4	-3.3	+25.7	+22.4
	0	-8.9	-4.7	-14.0	-18.7	-6.4	-25.1	+19.2	-5.9
	1	-7.4	-19.2	-11.6	-30.8	-10.5	-41.3	+11.8	-29.5
	3	-3.8	-26.6	-11.0	-37.6	-13.2	-50.8	+2.2	-48.6
	5	-2.3	-23.0	-9.8	-32.8	-12.9	-45.7	-1.2	-46.9
	7	-1.1	-18.8	-11.5	-30.3	-11.5	-41.8	-1.1	-42.9
	9	-0.6	-14.1	-9.2	-23.3	-9.8	-33.1	-1.2	-34.3
	11	-0.3	-8.2	-7.9	-16.1	-7.0	-23.1	-0.2	-23.3
	13	-0.1	-4.2	-4.2	-8.4	-2.9	-11.3	+0.2	-11.1
bamboo fence	7	+1.4	-2.1	+5.1	+3.0	-0.2	+2.8	-1.1	+1.7
	5	+1.1	+2.6	+5.4	+8.0	+1.9	+9.9	+0.1	+10.0
	3	+0.8	+24.8	+7.9	+32.7	-6.9	+25.8	-1.8	+24.0
	1	+9.5	-11.7	+26.2	+14.5	+3.8	+18.3	-15.0	+3.3
	0	-8.7	-48.3	+10.2	-38.1	+30.0	-8.1	+0.8	-7.3
	1	-0.6	-16.3	-6.6	-22.9	-3.4	-26.3	+7.8	-18.5
	3	-1.0	-17.6	-9.4	-27.0	-8.4	-35.4	+2.1	-33.3
	5	-0.9	-11.9	-11.4	-23.3	-8.1	-31.4	+1.1	-30.3
	7	-0.3	-11.5	-9.7	-21.2	-7.1	-28.3	+1.2	-27.1
	9	-0.4	-9.0	-8.7	-17.7	-5.7	-23.4	+3.0	-20.4
	11	-0.1	-2.5	-5.8	-8.3	-4.2	-12.5	+2.1	-10.4
	13	+0.3	+1.3	+0.5	+1.8	+1.5	+3.3	+2.3	+5.6

*1 average change in height of measuring piles (cm)

*2 cumulative change in height of measuring piles (cm)

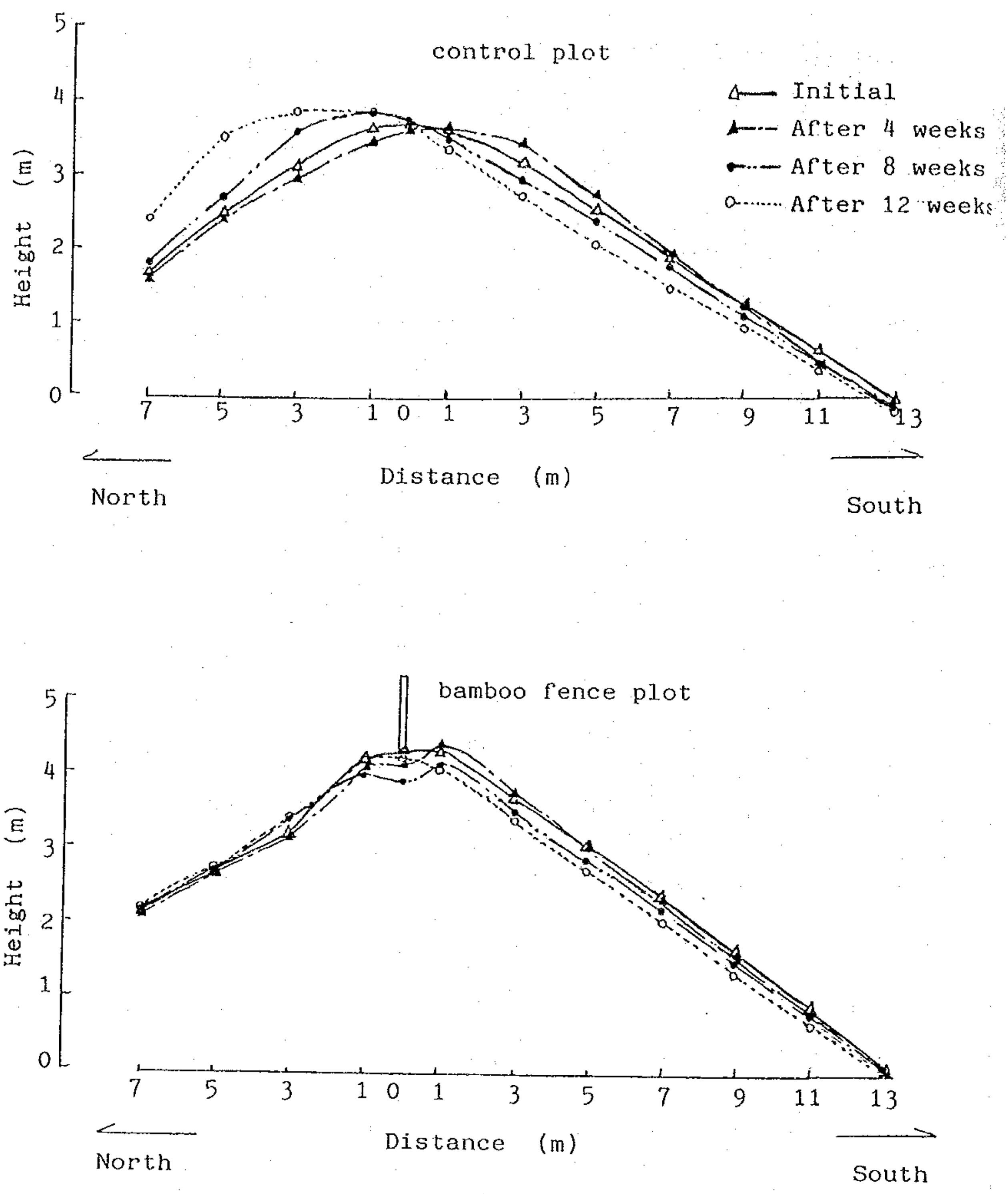


Fig. 6. Changes of the accumulated sand in each plot shown by cross section of sand dune used

Table 3. The amount of shifting sand

Treatment	Distance (m)	After 4 weeks		After 8 weeks		After 12 weeks	
		a *1	b *2	a	b	a	b
control	7-5	-0.21	-0.21	+3.83	+3.62	+11.32	+14.94
	5-3	-1.28	-1.28	+7.66	+6.38	+8.22	+14.60
	3-1	-2.20	-2.20	+8.43	+6.23	+2.07	+8.30
	1-0	-1.02	-1.02	+2.09	+1.07	-0.31	+0.76
	0-1	-0.25	-0.25	+0.07	-0.18	-1.11	-1.29
	1-3	+2.41	+2.41	-10.29	-7.88	-3.67	-11.55
	3-5	+3.78	+3.78	-7.25	-3.47	-4.34	-7.81
	5-7	+1.55	+1.55	-4.56	-3.01	-4.19	-7.20
	7-9	-0.29	-0.29	-2.15	-2.44	-3.68	-6.12
	9-11	-0.62	-0.62	-1.07	-1.69	-2.90	-4.59
	11-13	-0.47	-0.47	-0.51	-0.98	-1.85	-2.83
bamboo fence	7-5	-0.47	-0.47	+0.35	-0.12	+0.90	+0.78
	5-3	-0.25	-0.25	+2.05	+1.80	+0.76	+2.56
	3-1	-1.26	-1.26	+1.36	+0.10	+2.03	+2.13
	1-0	-1.09	-1.09	-0.95	-2.04	+2.19	+0.15
	0-1	-0.06	-0.06	-2.11	-2.17	+1.16	-1.01
	1-3	+1.29	+1.29	-3.98	-2.69	-1.54	-4.23
	3-5	+0.42	+0.42	-2.39	-1.97	-2.80	-4.77
	5-7	+0.09	+0.09	-1.53	-1.44	-2.76	-4.20
	7-9	-0.06	-0.06	-1.29	-1.35	-2.30	-3.65
	9-11	-0.27	-0.27	-0.50	-0.77	-1.59	-2.36
	11-13	-0.07	-0.07	-0.02	-0.09	-0.18	-0.27

*1 Accumulated amount of shifting sand during each 4 weeks of experiment (m^3)

*2 Cumulative amount of shifting sand (m^3)

Table 4. The preventive ratio of shifting sand

Period	C (m^3)	F (m^3)	P (%)
First 4 weeks	7.74	1.80	76.7
Second 4 weeks	22.08	3.76	83.0
Third 4 weeks	21.61	7.04	67.4
Total	51.43	12.60	75.5

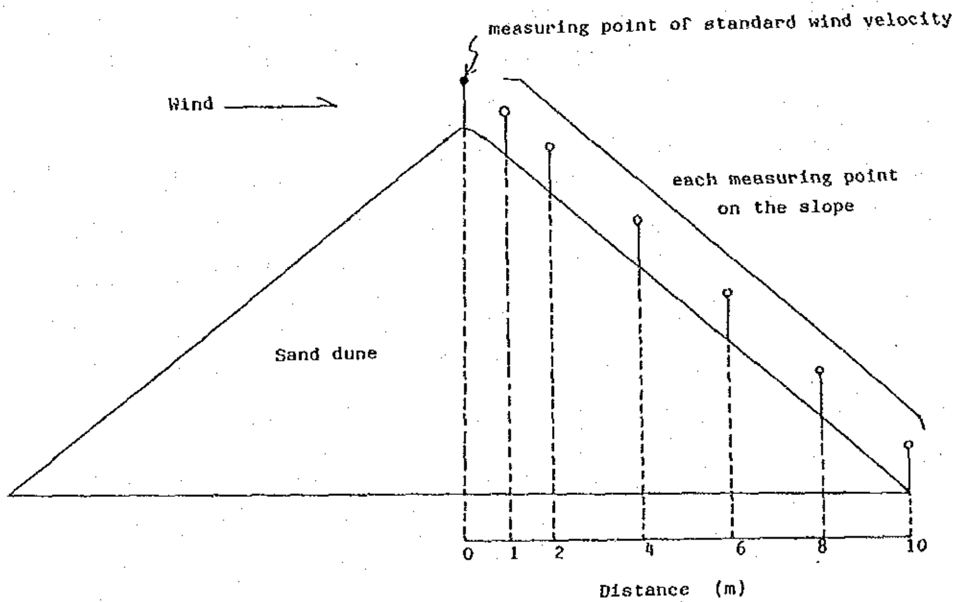
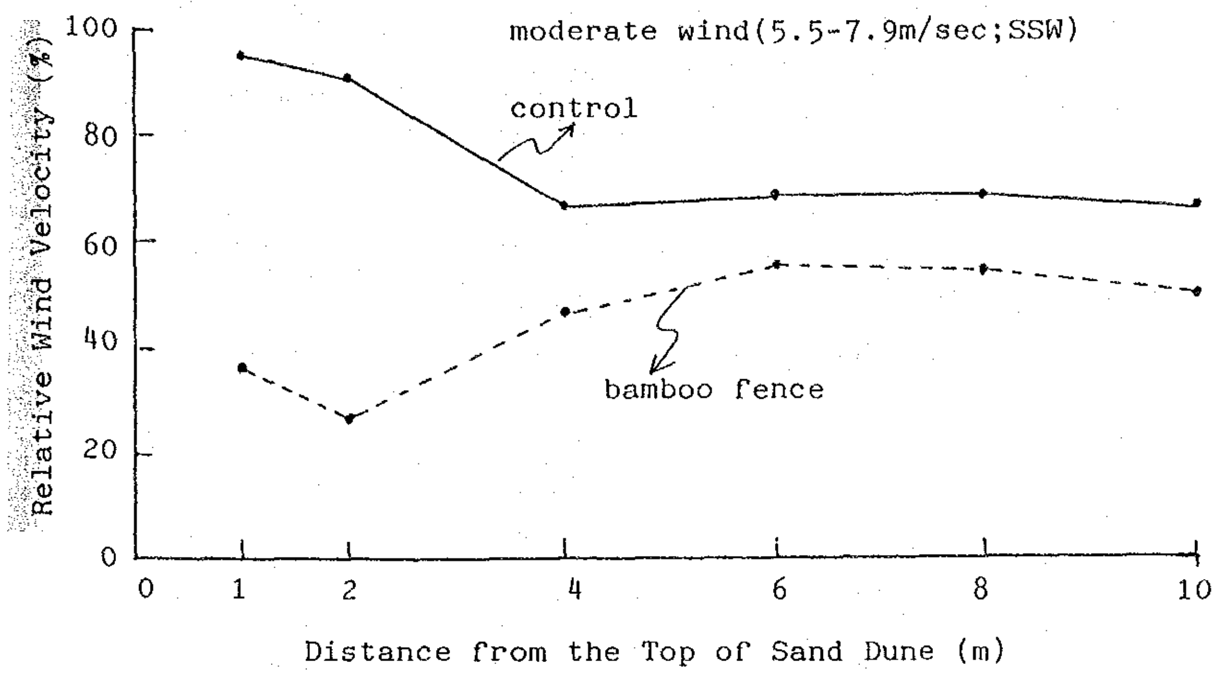


Fig. 7. Measuring point of wind velocity

Table 5. Average wind velocity and relative wind velocity

Class of wind velocity	Treatment	U (m/sec)	Distance (m) 1	2	4	6	8	10	Wind direction
moderate wind	control	6.5 (100)	6.2 (96)	5.9 (91)	4.3 (66)	4.4 (68)	4.4 (68)	4.2 (65)	SSW
	bamboo fence	6.3 (100)	2.3 (37)	1.7 (27)	2.9 (46)	3.6 (57)	3.4 (54)	3.0 (48)	SSW
strong wind	control	10.0 (100)	9.6 (96)	9.4 (94)	4.0 (40)	4.1 (41)	4.7 (47)	4.8 (48)	SSE
	bamboo fence	9.8 (100)	3.8 (39)	1.8 (18)	2.5 (26)	2.7 (28)	2.8 (29)	3.3 (34)	SSE



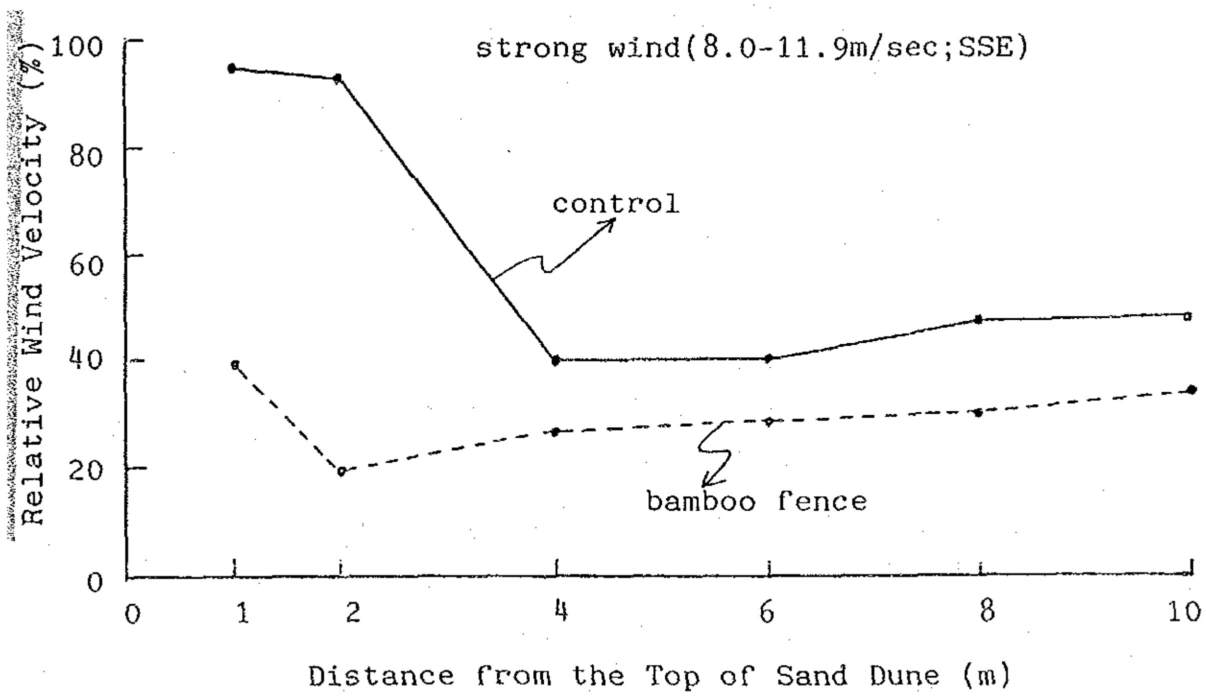


Fig. 8. Distribution of relative wind velocity

Table 6. Relationship between average wind velocity and TIS_{2H}

Wind velocity (m/sec)	Wind direction	TIS_{2H} (m^3)	
		control	bamboo fence
3.6	S-W(variable)	0.024	0.053
3.8	S-W(variable)	0.034	0.098
6.1	SSW	0.067	0.085
6.2	SSW	0.114	0.004
6.4	SSW	0.324	0.058
7.8	SSW	0.430	0.080
9.1	SSE	0.627	0.124
9.6	SSE	0.794	0.267
10.0	SSE	0.650	0.241
10.2	SSE	1.251	0.486
10.5	SSE	0.929	0.290

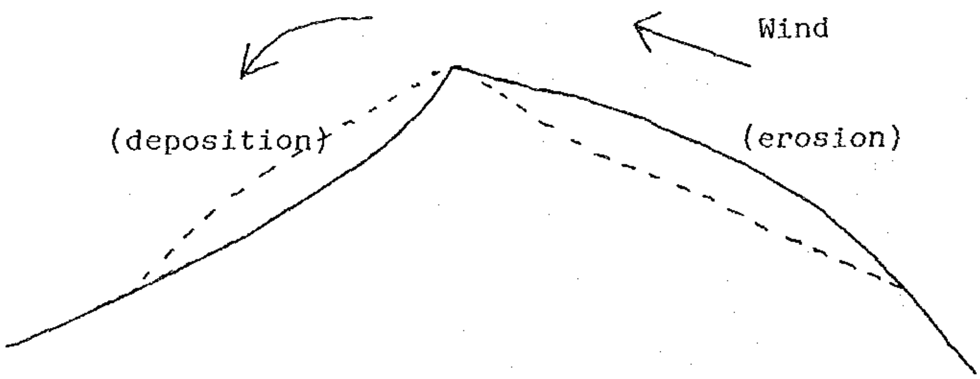


Fig. 9. Mode of sand movement

Table 7. Result of linear regression analysis

Lineal correlation coefficient, r	Linear regression equation	U min(m/sec)
0.9097	$y=-0.6466+0.1483x^{*}$	4.4

* x: Wind Velocity(m/sec), y: TIS_{2H} (m^3)

Table 8-1. Wind velocity (1)

Date: March 19, 1986; Time: 15:30-16:50; Wind Direction: SSW							
Control				Bamboo Fence			
D[1] (m)	W.V.[2] (m/sec) Top	W.V.[2] (m/sec) Slope	R.W.V.[3] (%)	D[1] (m)	W.V.[2] (m/sec) Top	W.V.[2] (m/sec) Slope	R.W.V.[3] (%)
1	5.8	5.7	98	1	7.5	2.3	31
2	6.9	5.7	83	2	5.0	3.0	60
4	8.4	5.2	62	4	6.2	4.6	74
6	5.5	3.7	67	6	7.9	5.6	71
8	5.4	3.8	70	8	6.1	4.7	77
10	-	-	-	10	-	-	-
Average	6.4	-	-	Average	6.4	-	-
1	6.7	6.7	100	1	5.5	2.7	49
2	6.1	5.4	89	2	6.6	2.7	41
4	6.0	4.2	70	4	5.1	4.1	80
6	5.4	4.7	87	6	4.8	4.2	88
8	6.3	4.4	70	8	6.3	5.2	83
10	-	-	-	10	-	-	-
Average	6.1	-	-	Average	5.6	-	-
Date: March 20, 1986; Time: 15:32-17:00; Wind Direction: WWN							
Control				Bamboo Fence			
D[1] (m)	W.V.[2] (m/sec) Top	W.V.[2] (m/sec) Slope	R.W.V.[3] (%)	D[1] (m)	W.V.[2] (m/sec) Top	W.V.[2] (m/sec) Slope	R.W.V.[3] (%)
1	6.7	6.7	100	1	6.3	3.9	62
2	6.7	6.6	99	2	7.5	5.5	73
4	7.5	7.4	99	4	6.5	6.2	95
6	6.5	6.2	95	6	7.4	7.1	96
8	6.9	6.4	93	8	7.1	6.1	86
10	6.7	6.1	91	10	5.9	4.8	81
Average	6.8	-	-	Average	6.8	-	-
1	7.2	7.1	99	1	6.9	5.8	84
2	7.8	7.4	95	2	7.4	6.2	84
4	7.1	7.1	100	4	7.0	6.8	97
6	7.8	7.7	99	6	6.2	4.9	79
8	8.0	7.2	90	8	6.6	5.2	79
10	7.0	5.8	83	10	6.6	5.2	82
Average	7.5	-	-	Average	6.8	-	-

NOTES 1) Distance from the top of sand dune or bamboo fence (m)
2) Wind Velocity (m/sec)
3) Relative Wind Velocity (Ratio of "SLOPE" to "TOP")

Table 8-2. Wind velocity (2)

Date: March 24, 1986: Time: 15:32-17:17: Wind Direction:variable							
Control				Bamboo Fence			
D[1] (m)	W.V.[2] (m/sec) Top	W.V.[2] (m/sec) Slope	R.W.V.[3] (%)	D[1] (m)	W.V.[2] (m/sec) Top	W.V.[2] (m/sec) Slope	R.W.V.[3] (%)
1	2.8	2.7	96	1	4.5	0	0
2	4.2	4.1	98	2	4.4	0.9	21
4	4.4	4.5	102	4	3.3	2.4	73
6	3.2	3.1	97	6	3.4	0.3	9
8	3.8	3.6	95	8	4.6	1.6	35
10	5.4	4.4	81	10	3.7	2.4	65
Average	3.8	-	-	Average	3.9	-	-
1	4.3	4.5	105	1	3.5	0	0
2	4.0	4.0	100	2	4.7	5.0	106
4	3.8	4.5	118	4	3.9	3.9	100
6	2.8	2.9	104	6	4.6	4.0	87
8	6.0	3.9	65	8	4.0	3.6	90
10	4.2	2.7	64	10	4.3	3.5	81
Average	3.6	-	-	Average	4.0	-	-
Date: March 25, 1986: Time: 08:57-10:24; Wind Direction: SSE							
Control				Bamboo Fence			
D[1] (m)	W.V.[2] (m/sec) Top	W.V.[2] (m/sec) Slope	R.W.V.[3] (%)	D[1] (m)	W.V.[2] (m/sec) Top	W.V.[2] (m/sec) Slope	R.W.V.[3] (%)
1	10.6	9.5	90	1	8.7	3.9	45
2	11.0	10.3	94	2	10.1	2.3	23
4	10.5	4.1	39	4	9.7	3.1	32
6	10.7	4.9	46	6	9.9	3.1	31
8	10.4	4.5	43	8	9.5	2.8	29
10	10.8	4.9	45	10	10.6	3.6	34
Average	10.7	-	-	Average	9.8	-	-
1	10.1	9.7	96	1	10.8	5.2	48
2	10.9	9.7	89	2	10.3	2.4	23
4	9.5	4.0	42	4	9.8	2.9	30
6	9.6	4.8	50	6	10.6	3.3	31
8	9.8	3.8	39	8	11.1	3.3	30
10	8.3	3.9	44	10	9.9	4.2	42
Average	9.8	-	-	Average	10.5	-	-

NOTES 1) Distance from the top of sand dune or bamboo fence (m)
2) Wind Velocity (m/sec)
3) Relative Wind Velocity (Ratio of "SLOPE" to "TOP")

Table 8-3 Wind velocity (3)

Date: March 25, 1986: Time: 15:42-17:20; Wind Direction: SSW							
Control				Bamboo Fence			
D[1]	W.V.[2] (m/sec)		R.W.V.[3]	D[1]	W.V.[2] (m/sec)		R.W.V.[3]
(m)	Top	Slope	(%)	(m)	Top	Slope	(%)
1	6.0	5.8	97	1	7.0	3.8	54
2	5.9	5.2	88	2	6.5	1.3	20
4	6.8	2.4	35	4	7.7	1.7	22
6	6.9	2.7	39	6	7.4	2.2	30
8	7.2	3.8	53	8	6.3	1.4	22
10	7.5	4.7	63	10	6.3	2.6	41
Average	6.8	-	-	Average	6.8	-	-
1	4.9	4.7	96	1	5.7	3.4	60
2	6.9	6.5	94	2	5.9	0.7	12
4	5.7	3.9	68	4	6.0	0.5	8
6	6.0	4.6	77	6	6.6	2.9	44
8	6.7	4.5	67	8	5.8	1.7	29
10	7.3	4.4	60	10	5.0	1.9	38
Average	6.2	-	-	Average	5.9	-	-
Date: March 31, 1986: Time: 08:48-10:43; Wind Direction: SSE							
Control				Bamboo Fence			
D[1]	W.V.[2] (m/sec)		R.W.V.[3]	D[1]	W.V.[2] (m/sec)		R.W.V.[3]
(m)	Top	Slope	(%)	(m)	Top	Slope	(%)
1	9.5	8.8	93	1	10.7	-	-
2	8.9	8.2	92	2	8.9	0	0
4	10.5	4.5	43	4	11.1	2.2	20
6	9.5	3.0	30	6	9.4	2.3	24
8	10.4	3.8	37	8	8.1	2.0	25
10	10.1	4.3	43	10	9.5	3.2	34
Average	9.8	-	-	Average	9.6	-	-
1	9.2	9.4	102	1	9.0	-	-
2	9.5	8.8	93	2	10.0	1.8	18
4	9.7	5.1	53	4	10.9	3.5	32
6	9.8	4.0	41	6	9.1	2.8	31
8	8.9	5.3	60	8	10.4	3.7	36
10	8.9	4.8	54	10	8.6	2.6	30
Average	9.3	-	-	Average	9.7	-	-

NOTES 1) Distance from the top of sand dune or bamboo fence (m)
2) Wind Velocity (m/sec)
3) Relative Wind Velocity (Ratio of "SLOPE" to "TOP")

Table 8-4. Wind velocity (4)

Date: April 1. 1986; Time: 08:48-10:22; Wind Direction: SSE

Control				Bamboo Fence			
D[1] (m)	W.V.[2] (m/sec) Top	W.V.[2] (m/sec) Slope	R.W.V.[3] (%)	D[1] (m)	W.V.[2] (m/sec) Top	W.V.[2] (m/sec) Slope	R.W.V.[3] (%)
1	8.3	8.4	101	1	10.0	3.4	34
2	11.6	10.7	92	2	10.0	2.6	26
4	9.1	3.5	38	4	11.1	3.2	29
6	10.9	4.6	42	6	10.0	2.8	28
8	10.0	4.8	48	8	9.2	2.9	32
10	10.5	4.6	44	10	9.5	4.4	46
Average	10.1	-	-	Average	10.0	-	-
1	10.1	10.3	102	1	9.7	3.5	36
2	9.9	9.1	92	2	10.3	2.5	24
4	10.5	3.8	36	4	11.2	3.0	27
6	10.3	3.9	38	6	9.7	2.6	27
8	8.8	4.4	50	8	9.4	3.3	35
10	10.0	5.1	51	10	10.3	3.0	29
Average	10.0	-	-	Average	10.1	-	-

Date: April 1. 1986; Time: 15:37-17:15; Wind Direction: SSW-SW

Control				Bamboo Fence			
D[1] (m)	W.V.[2] (m/sec) Top	W.V.[2] (m/sec) Slope	R.W.V.[3] (%)	D[1] (m)	W.V.[2] (m/sec) Top	W.V.[2] (m/sec) Slope	R.W.V.[3] (%)
1	6.5	6.2	95	1	6.5	1.4	22
2	5.6	5.2	93	2	6.2	2.6	42
4	7.3	5.4	74	4	7.5	4.0	53
6	6.8	5.2	76	6	6.6	4.6	70
8	7.4	6.1	82	8	4.9	3.2	65
10	7.4	5.0	68	10	7.0	4.4	63
Average	6.8	-	-	Average	6.4	-	-
1	5.4	5.1	94	1	5.5	1.5	27
2	6.5	6.0	92	2	5.7	0	0
4	4.9	3.7	76	4	6.4	3.6	56
6	6.9	5.0	72	6	5.8	3.7	64
8	5.8	4.6	79	8	5.4	3.5	65
10	4.8	3.8	79	10	4.5	2.6	58
Average	5.7	-	-	Average	5.5	-	-

NOTES 1) Distance from the top of sand dune or bamboo fence (m)
2) Wind Velocity (m/sec)
3) Relative Wind Velocity (Ratio of "SLOPE" to "TOP")

Table 8-5. Wind velocity (5)

Date: April 2, 1986: Time: 08:44-10:26; Wind Direction: SSE							
Control				Bamboo Fence			
D[1] (m)	W.V.[2] (m/sec) Top	W.V.[2] (m/sec) Slope	R.W.V.[3] (%)	D[1] (m)	W.V.[2] (m/sec) Top	W.V.[2] (m/sec) Slope	R.W.V.[3] (%)
1	11.6	10.5	91	1	10.5	3.6	34
2	11.3	10.6	94	2	10.4	2.6	25
4	10.7	4.0	37	4	10.7	3.2	30
6	9.1	3.9	43	6	9.4	2.4	26
8	10.2	4.9	48	8	10.5	3.1	30
10	11.2	5.5	49	10	11.5	3.4	30
Average	10.7	-	-	Average	10.5	-	-
1	10.9	10.4	95	1	9.7	3.7	38
2	10.6	10.3	97	2	10.2	1.7	17
4	11.1	3.7	33	4	10.8	2.6	24
6	11.1	4.1	37	6	10.7	2.0	19
8	10.3	5.3	51	8	9.8	2.6	27
10	10.4	4.8	46	10	9.8	3.5	36
Average	10.7	-	-	Average	10.2	-	-

Date: April 2, 1986: Time: 15:27-16:12; Wind Direction: SSW							
Control				Bamboo Fence			
D[1] (m)	W.V.[2] (m/sec) Top	W.V.[2] (m/sec) Slope	R.W.V.[3] (%)	D[1] (m)	W.V.[2] (m/sec) Top	W.V.[2] (m/sec) Slope	R.W.V.[3] (%)
1	8.1	7.5	93	1	7.2	0.9	13
2	8.6	8.4	98	2	8.1	1.3	16
4	7.5	5.6	75	4	7.4	1.9	26
6	8.0	4.7	59	6	8.0	2.6	33
8	7.8	4.2	54	8	8.0	2.7	34
10	7.1	3.8	54	10	7.3	2.9	40
Average	7.8	-	-	Average	7.7	-	-

NOTES 1) Distance from the top of sand dune or bamboo fence (m)
2) Wind Velocity (m/sec)
3) Relative Wind Velocity (Ratio of "SLOPE" to "TOP")

Table 8-6. **Wind velocity (6)**

Date: April 3, 1986; Time: 08:40-10:10; Wind Direction: SSE							
Control				Bamboo Fence			
D[1] (m)	W.V.[2] (m/sec) Top	W.V.[2] (m/sec) Slope	R.W.V.[3] (%)	D[1] (m)	W.V.[2] (m/sec) Top	W.V.[2] (m/sec) Slope	R.W.V.[3] (%)
1	9.0	8.5	94	1	8.7	3.3	38
2	9.0	8.8	98	2	9.2	1.4	15
4	9.7	3.6	37	4	9.5	1.8	19
6	9.4	3.8	40	6	9.4	2.2	23
8	9.0	4.0	44	8	8.8	2.2	25
10	9.4	4.7	50	10	9.2	2.8	30
Average	9.3	-	-	Average	9.1	-	-
1	8.9	8.4	94	1	9.7	3.7	38
2	9.3	9.0	97	2	8.4	0.9	11
4	9.3	3.9	42	4	8.1	1.7	21
6	9.8	3.9	40	6	8.3	3.6	43
8	9.2	4.3	47	8	8.6	2.0	23
10	9.7	5.1	53	10	8.8	2.6	30
Average	9.4	-	-	Average	8.7	-	-

Date: April 3, 1986; Time: 15:42-17:13; Wind Direction: variable							
Control				Bamboo Fence			
D[1] (m)	W.V.[2] (m/sec) Top	W.V.[2] (m/sec) Slope	R.W.V.[3] (%)	D[1] (m)	W.V.[2] (m/sec) Top	W.V.[2] (m/sec) Slope	R.W.V.[3] (%)
1	4.3	4.4	102	1	1.5	0	0
2	5.2	5.3	102	2	4.2	1.0	24
4	5.3	4.2	79	4	3.1	0	0
6	3.5	3.5	100	6	2.6	0	0
8	2.9	2.9	100	8	1.6	0	0
10	3.4	2.6	76	10	3.8	2.4	63
Average	4.1	-	-	Average	2.8	-	-
1	2.4	2.3	96	1	5.6	4.9	88
2	3.5	3.7	106	2	3.2	2.8	88
4	3.3	3.0	91	4	1.8	0	0
6	2.5	1.6	64	6	3.5	1.4	40
8	4.7	4.1	87	8	4.0	1.8	45
10	5.4	4.6	85	10	4.5	2.2	49
Average	3.6	-	-	Average	3.8	-	-

NOTES 1) Distance from the top of sand dune or bamboo fence (m)
2) Wind Velocity (m/sec)
3) Relative Wind Velocity (Ratio of "SLOPE" to "TOP")

Table 9-1. The amount of shifting sand (1)

March 19, 1986: 15:12-17:12			March 20, 1986: 15:15-17:15		
W.V.[1]:6.2m/sec; W.D.[2]:SSW			W.V.[1]: 7.0m/sec; W.D.[2]:WWN		
D[3] (m)	Amount of Shifting Sand(m3)		D[3] (m)	Amount of Shifting Sand(m^3)	
	Control	Bamboo Fence		Control	Bamboo Fence
N[4]:11-9	-	-	N[4]:11-9	-	-
9-7	-	-	9-7	-	-
7-5	-	- 0.025	7-5	-	0.014
5-3	0.113	0.002	5-3	- 0.056	0.008
3-1	0.001	- 0.023	3-1	- 0.019	- 0.075
1-0	- 0.053	0.002	1-0	0.056	0.003
S[5]:0-1	- 0.053	0.014	S[5]:0-1	0.056	0.043
1-3	- 0.067	- 0.014	1-3	0.070	0.027
3-5	- 0.043	- 0.012	3-5	0.002	0.023
5-7	- 0.034	- 0.008	5-7	- 0.013	0.011
7-9	- 0.027	- 0.003	7-9	- 0.004	0.017
9-11	- 0.009	0.009	9-11	0.012	0.019
TIS_{2H}	0.114	0.004	TIS_{2H}	-	-

March 24, 1986: 15:13-17:13			March 25, 1986; 08:35-10:35		
W.V.[1]:3.8m/sec; W.D.[2]:variable			W.V.[1]:10.2m/sec; W.D.[2]:SSE		
D[3] (m))	Amount of Shifting Sand(m^3)		D[3] (m)	Amount of Shifting Sand(m^3)	
	Control	Bamboo Fence		Control	Bamboo Fence
N[4]:11-9	- 0.018	- 0.021	N[4]:11-9	0.029	0.043
9-7	- 0.015	- 0.016	9-7	0.087	0.020
7-5	- 0.002	0	7-5	0.193	0.004
5-3	0.001	0.016	5-3	0.541	0.001
3-1	0.015	0.058	3-1	0.401	0.257
1-0	0.014	0.024	1-0	- 0.130	0.161
S[5] 0-1	0.004	0.001	S[5]:0-1	- 0.131	- 0.042
1-3	0.004	0.005	1-3	- 0.387	- 0.180
3-5	0.004	0	3-5	- 0.185	- 0.033
5-7	0.006	0	5-7	- 0.109	- 0.063
7-9	0.008	- 0.006	7-9	- 0.090	- 0.093
9-11	0.011	- 0.006	9-11	- 0.092	- 0.061
TIS_{2H}	0.034	0.098	TIS_{2H}	1.251	0.486

NOTES 1) Wind Velocity (m/sec)
2) Wind Direction
3) Distace from the top of sand dune or bamboo fence (m)
4) North side of sand dune
5) South side of sand dune

Table 9-2. The amount of shifting sand (2)

March 25.1986; 15:23-17:23		
W.V.[1]:6.4m/sec; W.D.[2]:SSW		
D[3] (m)	Amount of Shifting Sand(m3)	
	Control	Bamboo Fence
N[4]:11-9	0.018	0.018
9-7	0.044	0.007
7-5	0.082	- 0.009
5-3	0.132	0.004
3-1	0.048	0.021
1-0	- 0.035	0.008
S[5]:0-1	- 0.036	0
1-3	- 0.056	- 0.003
3-5	- 0.035	0.002
5-7	- 0.005	0.001
7-9	0.006	0.006
9-11	0.008	0.003
TIS_{2H}	0.324	0.058

March 31, 1986; 08:30-10:30		
W.V.[1]: 9.6m/sec; W.D.[2]:SSE		
D[3] (m)	Amount of Shifting Sand(m^3)	
	Control	Bamboo Fence
N[4]:11-9	0.075	0.024
9-7	0.047	0.022
7-5	0.086	0.001
5-3	0.468	0.004
3-1	0.018	0.134
1-0	- 0.163	0.082
S[5]:0-1	- 0.164	- 0.064
1-3	- 0.110	- 0.183
3-5	0.056	- 0.070
5-7	- 0.058	- 0.081
7-9	- 0.078	- 0.055
9-11	- 0.071	- 0.038
TIS_{2H}	0.794	0.267

April 1, 1986; 08:27-10:27		
W.V.[1]:10.0m/sec; W.D.[2]:SSE		
D[3] (m))	Amount of Shifting Sand(m^3)	
	Control	Bamboo Fence
N[4]:11-9	0.031	0.005
9-7	0.069	0.007
7-5	0.331	- 0.002
5-3	0.219	0.006
3-1	- 0.135	0.115
1-0	- 0.042	0.108
S[5] 0-1	- 0.043	0.024
1-3	- 0.136	- 0.092
3-5	- 0.106	- 0.036
5-7	- 0.090	- 0.069
7-9	- 0.077	- 0.068
9-11	- 0.058	- 0.015
TIS_{2H}	0.650	0.241

April 1, 1986; 15:18-17:18		
W.V.[1]:6.1m/sec; W.D.[2]:SSW		
D[3] (m)	Amount of Shifting Sand(m^3)	
	Control	Bamboo Fence
N[4]:11-9	0	0.004
9-7	0.005	0.012
7-5	0.036	0.018
5-3	0.026	0.033
3-1	- 0.030	0.007
1-0	- 0.010	0.011
S[5]:0-1	- 0.010	0.023
1-3	- 0.019	- 0.013
3-5	- 0.023	0.002
5-7	- 0.007	0.002
7-9	- 0.001	- 0.003
9-11	- 0.008	0.005
TIS_{2H}	0.067	0.085

NOTES 1) Wind Velocity (m/sec)
2) Wind Direction
3) Distace from the top of sand dune or bamboo fence (m)
4) North side of sand dune
5) South side of sand dune

Table 9-3 The amount of shifting sand (3)

April 2, 1986; 08:21-10:21			April 2, 1986; 15:07-16:07		
W.V.[1]:10.5m/sec; W.D.[2]:SSE			W.V.[1]: 7.8m/sec; W.D.[2]:SSW		
D[3] (m)	Amount of Shifting Sand(m3)		D[3] (m)	Amount of Shifting Sand(m^3)	
	Control	Bamboo Fence		Control	Bamboo Fence
N[4]:11-9	0.042	0.026	N[4]:11-9	- 0.001	- 0.003
9-7	0.245	0.035	9-7	0.057	0.001
7-5	0.478	0.010	7-5	0.099	0.004
5-3	0.164	0.003	5-3	0.059	0.031
3-1	- 0.169	0.145	3-1	- 0.045	0.003
1-0	- 0.090	0.071	1-0	- 0.031	0.001
S[5]:0-1	- 0.090	- 0.048	S[5]:0-1	- 0.032	0.014
1-3	- 0.164	- 0.052	1-3	- 0.049	- 0.011
3-5	- 0.157	- 0.029	3-5	- 0.048	- 0.013
5-7	- 0.147	- 0.072	5-7	- 0.036	- 0.007
7-9	- 0.132	- 0.094	7-9	- 0.010	0.001
9-11	- 0.102	- 0.062	9-11	- 0.007	0
TIS_{2H}	0.929	0.290	TIS_{2H}	0.430	0.080

April 3, 1986; 08:21-10:21			April 3, 1986; 15:19-17:19		
W.V.[1]:9.1m/sec; W.D.[2]:SSE			W.V.[1]:3.6m/sec; W.D.[2]:variable		
D[3] (m))	Amount of Shifting Sand(m^3)		D[3] (m)	Amount of Shifting Sand(m^3)	
	Control	Bamboo Fence		Control	Bamboo Fence
N[4]:11-9	0.099	0.018	N[4]:11-9	0.002	0.010
9-7	0.181	0.016	9-7	0.001	0.008
7-5	0.247	0.003	7-5	0	0.008
5-3	0.100	0.009	5-3	0.013	0.015
3-1	- 0.120	0.061	3-1	0.008	0.008
1-0	- 0.061	0.017	1-0	- 0.001	0.004
S[5] 0-1	- 0.062	- 0.028	S[5]:0-1	- 0.001	0.006
1-3	- 0.097	- 0.045	1-3	0.007	0.001
3-5	- 0.069	- 0.041	3-5	0.010	0.004
5-7	- 0.048	- 0.027	5-7	0.009	0.013
7-9	- 0.051	- 0.013	7-9	0.006	0.010
9-11	- 0.037	- 0.010	9-11	0.002	0.007
TIS_{2H}	0.627	0.124	TIS_{2H}	0.024	0.053

NOTES 1) Wind Velocity (m/sec)
2) Wind Direction
3) Distace from the top of sand dune or bamboo fence (m)
4) North side of sand dune
5) South side of sand dune

2. Relationship between captured amount of blowing sand and height from ground surface in sandy flat area (Theme A)

Abstract

The experiment on the measurement of amount of blowing sand in sandy flat area was carried out in order to determine the relationship between captured amount of blowing sand and height from ground surface.

The results obtained are as follows:

(1) Captured amounts of the blowing sand increased with a decrease in the height from ground surface, and the greater part of sand was obtained at the height of 0.2m.
(2) The ratio of coarse sand fraction in captured sand increased with a decrease in height.
(3) From the results, it was indicated that the greater part of blowing sand shifts at height of less than 0.2m in sandy flat area.

The experiment on the relationship between captured amount of blowing sand and height from ground surface in the sandy flat area of theme A plot was carried out by using a new type of sand capute equipment.

Materials and Methods

The amount of blowing sand with different particle-sizes was measured by the sand capture equipment with revolving system[1] The equipment were respectively set up in different heights of 0.2, 0.5, 1.0 and 1.5m from ground surface in the middle site of theme A plot. The soil texture in theme A plot was loamy fine sand. The measurement was started from April, 1986 and is still continued in the present time.

Results and discussion

The results of captured amounts of blowing sand in different heights from ground surface from April to August were shown in Table 10.

Captured amounts of the blowing sand increased in accordance to a decrease in the height from ground surface, and more than 90% of the sand was captured at height of 0.2m. This indicates that the greater part of blowing sand shifts at the height of less than 0.2m in sandy flat area. The results obtained are similar to informations by Bagnold[2], Nemoto[3] and Ishihara[4]. Also captured amounts of the sand were higher in June to August in comparison with the case of April to May.

Table 11 and 12 show the results of particle size distributions of the captured sand in different heights from ground surface.

In these results, the fraction of coarse sand in captured sand increased and fractions of fine sand, silt and clay in captured sand decreased with a decrease in the height from ground surface.

The sand captured equipment with revolving system have an advantage that is possible to capture the blowing sand corresponding to wind direction. The equipment, however, has a weak point that is difficult to measure to blowing sand at low situation less than 0.2m from ground surface. Therefore, in the case of measurement of shifting sand at low situation, this equipment is needed to be improved in future or other equipment such as box type should be used.

Literature cited

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Table 10. Captured amounts of the blowing sand in different heights from ground surface during April to August, 1986

Height(m)	Captured amount of blowing sand(g)				
	April	May	June	July	August
1.5	9.1 (1.7)	3.7 (1.4)	77.4 (1.5)	10.5 (1.3)	4.9 (0.6)
1.0	8.3 (1.6)	2.7 (1.0)	104.0 (2.0)	12.8 (1.6)	6.8 (0.9)
0.5	25.5 (4.8)	7.1 (2.6)	717.7 (13.8)	40.7 (5.1)	25.7 (3.3)
0.2	487.9 (91.9)	257.4 (95.0)	4310.8 (82.7)	736.7 (92.0)	739.4 (95.2)
Total	530.8 (100.0)	270.9 (100.0)	5209.9 (100.0)	800.7 (100.0)	776.8 (100.0)

Figures in perentheses show percentage

Table 11. Particle-size distributions of captured sands in different heights from ground surface (1)

Soil particle size(mm)	Particle size distribution(%)				
	Height(m)				original soil
	0.2	0.5	1.0	1.5	
2.0 >	--	--	--	--	--
1.4 -2.0	--	--	--	--	--
1.0 -1.4	0.11	0.12	0.04	--	--
0.5-1.0	6.08	6.78	1.63	0.21	1.68
0.212-0.5	44.59	44.82	16.48	9.00	36.38
0.106-0.212	45.07	38.45	60.81	62.03	46.95
0.053-0.106	4.06	9.57	20.37	28.25	13.91
0.053 <	0.10	0.25	0.54	0.51	0.89

Table 12. Particle-size distributions of captured sands in different heights from ground surface (2)

Fraction	Particle-size distribution (%)				
	Height(m)				original soil
	0.2	0.5	1.0	1.5	
Coarse sand (0.212-2 mm)	50.78	51.72	18.15	9.21	38.36
Fine sand (0.053-0.212mm)	49.13	48.02	81.18	90.28	60.86
Silt + Clay (0.053mm <)	0.14	0.25	0.54	0.51	0.89

3. Studies on the chemical and physical properties of soil and well water in the University Farm (Theme A, B and C)

Abstract

Some chemical and physical properties of soils and well water from the Farm were investigated. The result obtained were as follows:

(1) Values of EC ranged from 0.59 to 0.61 mS/cm and those of SAR(Sodium Adsorption Ratio) from 1.31 to 1.47 in saturation extract of soil samples. Accordingly the salinity of soil sample was low level as shown in C2–S1 classified from criteria of U.S. Salinity Laboratory.

(2) The texture of soil sample was classified in loamy fine sand.

(3) Soil samples contained about 20% of carbonate. The carbonate was suggested to mainly originate in fine sand fraction.

(4) The sample of well water was found to be low salinity as shown in C3–S1.

Several trees and crops will be planted for experiments on the Joint Study Project in the University Farm near future. So we need to understand the characteristics of soil and well water used for the plants. In the present paper, some chemical and physical properties of soil and well water from the farm were investigated.

Materials and Methods

Soils in the Farm were collected from the surface layer of theme A plot. EC, pH, Soluble cations and anions in saturation extracts of soil samples were determined. The saturation method was obtained according to the method of U.S. Salinity Laboratory. EC and pH was measured with electrical conductivity meter and glass-electroad pH meter, respectively. Calcium and magnesium were determined with titration method using ethylenediamine tetraacetate. Chloride was determined with titration method using silver nitrate and carbonate and bicarbonate using surphuric acid. Sodium and potassium was determined with flamephotometer. Sulphate was measured with turbidity of barium sulphate.

The mechanical composition of soil samples were analyzed by the method of International Society of Soil Science, and the effect of hydrochloric acid treatment on the particle-size distribution was examined. Fractions of silt and clay were determined pipetting method instead of using a hydrometer.

Result and Discussion

The results of EC, pH and ion composition in saturation extracts of soil samples were shown in Table 13.

Concentration of each ion in soil samples was low. Values of EC ranged from 0.59 to 0.62 mS/cm, and those of SAR(Sodium Adsorption Ratio) from 1.31 to 1.47. From these results, the salinity in saturation extract of soil samples was classified in C2–S1 according to criteria of Salinity

Laboratory, and was found to be low.

Table 14 shows the results of mechanical composition of soil samples. From the results, the texture of soil samples was classified in loamy fine sand. The fine sand fraction in soil sample at bottom area of the sand dune was larger than that in soil sample at top area. This shows that fine sand at top area is easy to shift by wind to bottom area.

Soil samples included about 20% of carbonates. On the other hand, about 20% of fine sand contents in soil samples decreased by the treatment of hydrochloric acid. This results suggests that carnonates in soil samples mainly originate in fine sand fraction.

Table 15 shows the results of EC, pH and ion composition in well water sample.

It was found to be low in both value of EC and concentration of each ion. Concentration of Na, Mg in cations and those of Cl, HCO_3 were relatively higher, respectively. From values of EC and SAR, sample water was classified in C3−S1 and was found to be relatively low in salinity.

Table 13. EC, pH and ion composition in sturation extracts of soil samples

	Soil-1 *1	Soil-2 *2
EC_e(mS/cm)	0.59	0.62
pH	8.32	8.43
Ca(me/1;ppm)	1.80(36.1)	1.65(33.1)
Mg	1.24(15.1)	1.45(17.6)
K	0.51(20.0)	0.77(30.0)
Na	1.61(37.0)	1.83(42.0)
CO_3	--	--
HCO_3	1.96(119.6)	1.95(119.0)
Cl	1.94(68.9)	1.85(65.7)
SO_4	1.11(53.3)	1.15(55.0)
SAR	1.31	1.47

*1 From the top area of sand dune

*2 From the lower area of sand dune

Table 14. **Mechanical composition of soil samples**

Soil	Coarse sand (%)	Fine sand (%)	Silt (%)	Clay (%)	Carbonate (%)	Soil Texture
1	35.1 (36.1)	60.0 (61.9)	0.7 (0.7)	1.3 (1.3)	2.9	Loamy fine sand
HCl-1*	36.4 (46.0)	40.1 (50.7)	1.4 (1.8)	1.2 (1.5)	20.9	
2	20.1 (21.4)	71.0 (75.4)	2.2 (2.3)	0.8 (0.9)	5.9	Loamy fine sand
HCl-2*	26.1 (31.4)	53.8 (64.7)	3.1 (3.7)	0.2 (0.2)	16.8	

* Soil-1 and -2 samples treated with HCl

Table 15. **EC, pH and ion composition in the sample of well water in the University Farm**

EC(mS/cm)	0.92
pH	8.69
Ca(me/1;ppm)	0.75(15.0)
Mg	3.46(42.1)
K	0.10(4.0)
Na	4.22(92.0)
CO_3	0.41(24.6)
HCO_3	3.28(200.1)
Cl	4.23(150.2)
SO_4	1.20(57.5)
SAR	2.91
Class	C3-S1

4. The effects of a subsurface compost layer on water preservation in sandy soil (Theme B)

Abstract

The experiment on the effects of compost layers laid in different depths from surface in the sandy soil near the University Farm was carried out in order to determine the preservation of irrigation water.

The result obtained are as follows:

(1) Moistrure in the compost (Al Ain compost used) layer laid in the depth of 10 (C-10 plot) and 20 (C-20 plot) cm from soil surface were higher than that in the control plot.

(2) The translocation of leaching water towards the lower parts from the compost layers in C-10 and C-20 plots became to be small in comparison with the control plot. The result was considered to be due to difficulty in translocation of irrigated water absorbed by the compost layers to the lower part.

(3) From the result above, an artificial compost layer in a subsurface soil was indicated to raise the preservation of irrigation water in compost layer including its upper part.

An effective use of irrigation water is one of the most important problems in arid land agriculture. Koto and Matsuda[1,2] reported that water retentivity in root zone was studied by thick laying the bark compost underground under irrigation of saline water in sandy soil in rainfall defence glasshouse, and that yields of crop plants increased as results of enlargement of the water storage in root zone and the salt injury for plants was mitigated. From the basis of results above mentioned, the present paper is concerned with the effectiveness of a subsurface Al Ain compost layer on water preservation in sandy soil of UAE. (This was conducted as the preliminary study for theme B (or "irrigation and water retnetivity in soil")).

Materials and Methods

The treatments, replicated one time,consisted of three levels of depth of the layer: C-10, C-20, control. The area of plot was 3.75m^2 and Al Ain compost was applied in amount of 30 tons/ ha. in the C-10 and C-20 plots, the compost was laied as two lines with width of about 25cm and with thick layer of about 3 to 5cm in the depth of 10 and 20cm from surface of an uncultivated sandy soil in the Central laboratory, Department of Agriculture, Government of UAE near the University Farm. Each plot was irrigated all at once with 40 mm of tap water. Soil samples from different layers of plots was collected in 1, 3, 5 and 9 days after irrigation. Soil moistures by weight in samples were determined.

Results and Discussion

The results were shown in Fig. 10. The front part of leaching water irrigation progressed from 29cm in 1st day to 37 cm in 9th day after treatment in control plot. Values of moisture gradually decreased towards subsurface layer. But the moisture in surface layer falled by evapolation in comparison with the just lower layer.

Moisture of the compost and the upper layers in C-10 plot were higher than those of control plot and increased with the course of time after treatment. And the translocation of leaching water towards the lower part from the compost layer became to be smaller than that of control plot. This was considered to be due to absorption of irrigated water in the compost layer and to difficulty in translocation of water basorbed by the compost layer to the lower part.

The distribution in moisture of each layer in C-20 plot was almost same as that of C-10 plot. But the moisture of upper part of the compost layer in C-20 plot was lower than that in control plot, and also the moisture of the compost layer and the translocation of water to the lower part from the compost layer in C-20 plot were smaller than those in C-10 plot.

The reasons of differences in moisture of each soil layer among plots were considered as follows:

The compost layer in the subsurface soil would have a high water-retentivity. Accordingly the moisture existed in the upper part of the compost layer in C-20 plot would translocate to the compost layer through the soil capillary pore and the absorbed by the layer. As the result, the moisture in the upper part of the compost layer in C-20 plot would decreased in comparison with the corresponding part in control plot.

On the other hand, the high preservation of water in the upper part of the compost layer which would have much more amount of soil in C-20 plot in comparison with C-10 plot would bring about the fall of preservation of water in the compost layer of C-20 plot, and then the translocation of the water to the lower part from the compost layer would deteriorate in C-20 plot.

From the results above, the artificial compost layer in a subsurface soil was indicated to raise the preservation of water in compost and its layers. .

Literature cited

1) KOTO, A. and MATSUDA, K., Effects of a subsurface bark compost layer on water retentivity, salinity and growth of crop plants in arid land. I. Water retentivity and crop yields as influenced by application methods of bark compost in sandy soil, Abstracts of the 1984 Meeting, Japanese Society of Soil Science and Plant Nutrition, vol. 30, p. 310 (in Japanese)

2) KOTO, A. and MATSUDA, K., Effects of a subsurface bark compost layer on water retentivity, salinity and growth of crop plants in arid land. III. Changes of water storage and salinity, and responce of crop plants to the subsurface compost layer under irrigation of saline water in sandy soil, Abstracts of the 1985 Meeting, Japanese Society of Soil Science and Plant Nutrition, vol. 31, p. 122 (in Japanese)

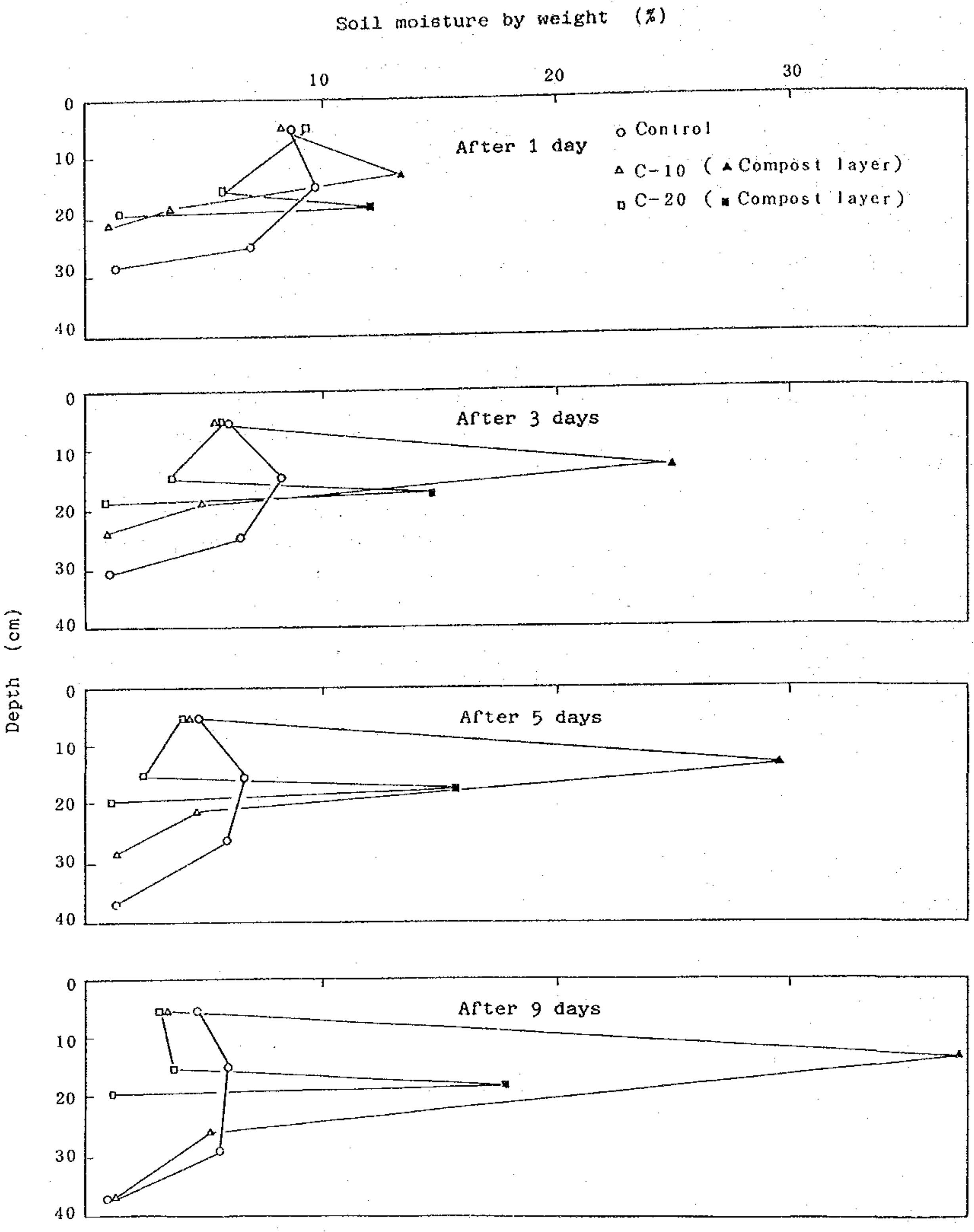

Fig. 10. Progressive changes of moisture in compost layers laid in depth of 10 and 20 cm from surface in field sandy soil

5. Effects of amount and quality of irrigation water, and different months of transplanting on the growth of Samar (*Acacia tortilis*) and Ghaff (*Prosopis spicigera*) (Theme A and C)

5–1. Effects of amount and quality of irrigation water on the growth of Samar (*Acacia tortilis*) and Ghaff (*Prosopis spicigera*).

This study is conducting in order to inquire effects of amount and quality of irrigation water on the growth of Samar and Ghaff.

5–1–1. Effect of amount of irrigation water

The young seedlings of Samar and Ghaff were transplanted on May 21, 1986 at Al Oha (villa's garden in Central Laboratory). Amount of irrigation water was 10 litre/day for each tree at first stage. EC and pH of irrigation water used are shown in Table 16. Treatment of irrigation amount was initiated from June 3, 1986. Experiment was consisted of 10 litre/day in high amount plot and 5 littre/day in low amount plot. Ten seedlings of each plot were used in each plot.

Plant growth (height and diameter), soil moisture, EC and pH in saturated extracts of soil are measured monthly.

Diural changes of soil temperature of different soil layers were also measured at the depth of 5, 10, 20, 30 and 50 cm from soil surface, respectively in each plot.

The results are shown in Table 17, 18, 19 and 20.

5–1–2. Effect of quality of irrigation water

The experiment was carried out in two sites. One was in the site of low salinity of irrigation water. Its site was same as experiment 2–1–1. The other was in the site of high salinity of irrigation water. Its site was the afforestation area of Forestry Department at Al Wagon. The quality of irrigation water is shown in Table 16.

Young Seedlings of Samar, Ghaff and Arak (*Salvadora persica*) were transplanted in April and May, 1986 in the site of Al Wagon.

Plant growth (height and diameter), soil moisture, EC and pH in saturation extracts of soil samples were measured monthly. Soil samples were collected from 0–1, 1–10, 10–30, 30–50, 50–70 and 70–100 cm below soil surface, respectively.

The results are shown in Table 21, 22 and 23.

5–2. Effect of different months of transplanting on the growth of Samar and Ghaff

This study is conducting in order to determine the most suitable time for transplanting of Samar and Ghaff. The experiment was started from May 21, 1986. Each ten seedlings of Samar and Ghaff were transplanted every month.

The remaining proportion in plants used and the growth in height and diameter of plant were measured monthly.

The results until now are shown in Table 24.

The transplanting experiment will be continued for one year.

Table 16. The quality of irrigation water in experimental sites

Experimental site	EC(mS/cm)	pH
Al Oha	0.72	8.2
Al Wagon	11.30	7.7

Table 17. The growth of Samar and Ghaff in Al Oha (May to August, 1986)

Species		Amount of irrigation water	May 22	June 5	June 25	July 23	August 25
Samar (Acasia tortilis)	Height(cm)	5L	75 ± 24 (100)	75 ± 24 (100)	86 ± 24 (115)	88 ± 23 (117)	87 ± 23 (116)
		10L	76 ± 13 (100)	77 ± 13 (101)	81 ± 17 (107)	90 ± 17 (118)	95 ± 18 (125)
	Diameter(mm)	5L	-	-	8.2 ± 0.4	9.2 ± 0.8	11.4 ± 0.9
		10L	-	-	7.6 ± 0.5	8.8 ± 0.4	12.0 ± 1.6
Ghaff (Prosopis spicigera)	Height(cm)	5L	60 ± 8 (100)	60 ± 8 (100)	63 ± 8 (105)	64 ± 16 (107)	76 ± 30 (127)
		10L	61 ± 17 (100)	63 ± 19 (103)	67 ± 20 (110)	74 ± 17 (121)	106 ± 24 (174)
	Diameter(mm)	5L	-	-	6.6 ± 0.5	7.8 ± 0.8	9.8 ± 1.3
		10L	-	-	8.2 ± 0.8	10.4 ± 1.1	15.0 ± 1.6

Table 18. Changes of moisture in soil samples from different layers in Al Oha (June to August, 1986)

Depth of soil layer ..(cm)	June 4		June 24		July 23		August 25	
	5ℓ	10ℓ	5ℓ	10ℓ	5ℓ	10ℓ	5ℓ	10ℓ
0-1	1.3	1.0	1.6	1.5	1.0	0.7	1.2	1.3
1-10	5.2	6.9	4.8	4.6	4.3	4.0	5.6	4.4
10-30	6.9	6.7	5.4	5.9	5.6	8.1	5.2	5.6
30-50	6.7	7.8	6.3	8.5	5.8	6.1	4.9	6.5
50-70	10.5	10.1	8.9	11.3	10.9	8.1	7.3	7.7
70-100	9.5	11.7	9.1	10.2	10.0	12.5	9.1	13.4

Table 19. Changes of pH and EC* in saturation extracts of soil samples from different layers in Al Oha (June to August, 1986)

Depth(cm) of soil layer	June 4 5L pH	June 4 5L EC	June 4 10L pH	June 4 10L EC	June 24 5L pH	June 24 5L EC	June 24 10L pH	June 24 10L EC	July 23 5L pH	July 23 5L EC	July 23 10L pH	July 23 10L EC	August 25 5L pH	August 25 5L EC	August 25 10L pH	August 25 10L EC
0-1	8.0	3.2	8.0	3.1	8.2	2.0	8.2	1.5	7.4	2.0	8.0	2.1		1.9		1.6
1-10	8.1	0.6	8.0	0.5	8.2	0.5	8.3	0.4	7.6	0.6	7.7	0.5		0.6		0.6
10-30	8.0	0.7	7.9	0.7	8.2	0.5	8.0	0.4	7.4	1.3	7.8	2.6		1.5		1.4
30-50	7.9	0.7	8.1	0.7	8.3	0.7	8.2	0.5	7.1	1.3	7.8	1.2		1.9		1.5
50-70	8.0	1.8	8.0	0.9	8.2	0.8	8.5	0.7	7.8	1.7	7.6	0.7		1.9		2.0
70-100	8.1	3.7	8.1	2.0	8.3	1.0	8.0	1.0	7.9	1.8	7.9	1.8		1.1		2.0

* mS/cm

Table 20-1. Diurnal changes of air temp., water temp. and soil temp. of different soil layer

DATE: JULY 11, 1986								
TIME	6:00	6:30	7:00	8:00	9:00	10:00	11:00	12:00
Air Temp.(°C)	23.0	25.1	28.6	32.0	35.5	39.8	41.5	43.5
Water Temp.(°C)	33.0	–	31.0	29.2	29.0	29.6	30.3	31.2
cont. 5cm	35.0	34.2	34.0	34.4	35.7	37.7	39.9	42.1
10cm	39.5	39.2	39.0	38.8	38.7	38.7	39.2	39.9
20cm	39.6	39.5	39.5	39.3	39.2	39.1	39.0	39.1
30cm	39.9	39.9	39.9	39.8	39.8	39.8	39.7	39.6
50cm	38.5	38.5	38.6	38.8	38.8	39.0	39.1	39.1
5L plot 5cm	29.8	30.7	29.5	29.0	30.1	31.6	34.6	37.5
10cm	33.2	32.5	32.5	31.9	31.8	32.6	34.4	36.4
20cm	36.0	35.8	35.5	35.2	34.8	34.6	34.7	35.2
30cm	38.0	37.7	37.6	37.4	37.3	37.0	36.9	36.8
50cm	38.0	38.0	38.1	38.2	38.3	38.3	38.3	38.3
10L plot 5cm	31.3	32.4	30.7	29.6	29.7	31.5	33.9	35.8
10cm	32.1	31.9	31.8	31.2	31.3	31.9	33.1	34.5
20cm	34.7	34.3	34.1	33.8	33.5	33.4	33.7	34.3
30cm	36.8	36.7	36.7	36.6	36.3	36.2	36.1	36.0
50cm	36.6	36.7	36.7	36.7	36.7	36.7	36.8	36.8

Table 20-2. Diurnal change of air temp., water temp. and soil temp. of different soil layer

DATE: JULY 11. 1986							
TIME	13:00	14:00	15:00	16:00	17:00	18:00	19:00
Air Temp.(°C)	44.7	45.0	45.1	44.9	43.2	41.0	37.1
Water Temp.(°C)	32.9	34.6	35.1	35.1	35.0	34.2	34.0
cont. 5cm	44.4	46.4	47.8	48.7	48.7	48.4	47.3
10cm	41.1	42.0	43.0	43.7	44.3	44.6	44.7
20cm	39.1	39.3	39.5	39.7	40.0	40.2	40.5
30cm	39.5	39.5	39.5	39.5	39.5	39.6	39.7
50cm	39.2	39.2	39.2	39.2	39.0	39.0	38.8
5L plot 5cm	39.8	41.5	43.2	44.0	43.7	42.5	40.6
10cm	38.6	40.2	41.7	42.5	42.9	42.5	41.8
20cm	36.0	37.0	37.9	38.7	39.5	39.9	40.1
30cm	36.9	37.0	37.2	37.6	37.9	38.2	38.5
50cm	38.3	38.2	38.1	38.0	38.0	37.9	37.9
10L plot 5cm	37.8	39.6	40.6	41.3	41.2	40.6	39.8
10cm	36.0	37.2	38.1	39.0	39.4	39.4	39.1
20cm	35.4	36.4	37.4	38.3	39.1	39.6	39.7
30cm	36.1	36.1	36.3	36.5	36.8	37.1	37.3
50cm	36.8	36.7	36.7	36.7	36.6	36.5	36.4

Table 20-3. Diurnal changes of air temp., water temp. and soil temp. of different soil layer

DATE: JULY 18, 1986									
TIME		6:00	6:30	7:00	8:00	9:00	10:00	11:00	12:00
Air Temp.(°C)		24.5	25.0	28.8	35.2	39.0	41.7	43.0	44.5
Water Temp.(°C)		33.3	32.4	31.9	30.0	29.6	30.0	30.7	32.0
cont.	5cm	36.3	35.7	35.5	35.6	36.6	38.1	40.3	42.8
	10cm	40.9	40.5	40.5	40.2	40.0	39.9	39.9	40.5
	20cm	40.1	40.0	40.0	39.9	39.8	39.7	39.7	39.5
	30cm	40.1	40.0	40.0	40.1	40.1	40.0	40.0	40.0
	50cm	38.6	38.6	38.6	38.9	39.1	39.2	39.3	39.4
5L plot	5cm	30.0	30.9	30.2	29.6	30.2	33.6	37.1	39.5
	10cm	33.0	32.5	32.6	31.9	31.8	32.9	35.1	37.4
	20cm	35.8	35.5	35.4	35.1	34.7	34.5	34.6	35.0
	30cm	37.5	37.4	37.4	37.3	37.1	36.9	36.7	36.6
	50cm	38.0	38.0	38.1	38.3	38.3	38.3	38.3	38.3
10L plot	5cm	31.7	31.9	31.8	30.4	29.9	30.6	32.6	35.1
	10cm	32.2	31.4	31.9	31.6	31.3	31.7	32.7	34.5
	20cm	34.5	34.4	34.1	34.1	33.7	33.5	33.6	34.3
	30cm	37.0	36.9	36.8	36.7	36.6	36.5	36.3	36.2
	50cm	36.7	36.7	36.7	36.7	36.8	36.8	36.9	36.9

Table 20-4. Diurnal changes of air temp., water temp. and soil temp. of different soil layer

DATE: JULY 18. 1986							
TIME	13:00	14:00	15:00	16:00	17:00	18:00	19:00
Air Temp.(°C)	44.8	44.0	44.8	43.3	41.7	40.0	38.5
Water Temp.(°C)	33.5	35.9	36.3	35.9	35.0	34.0	33.0
cont. 5cm	45.1	47.0	48.5	49.5	49.6	49.1	47.8
10cm	41.4	42.2	43.2	43.9	44.6	45.0	45.2
20cm	39.6	39.6	39.7	39.8	40.0	40.1	40.3
30cm	39.9	39.8	39.8	39.7	39.7	39.7	39.7
50cm	39.5	39.4	39.4	39.4	39.2	39.2	39.1
5L plot 5cm	40.8	41.6	43.1	43.6	43.2	41.7	39.6
10cm	39.4	40.5	42.1	42.8	42.9	42.4	41.3
20cm	35.7	36.5	37.6	38.4	39.1	39.5	39.6
30cm	36.7	36.7	37.0	37.4	37.7	38.0	38.2
50cm	38.2	38.2	38.1	38.1	38.0	38.0	38.0
10L plot 5cm	37.4	38.9	40.3	40.8	40.7	40.1	39.3
10cm	35.8	36.6	37.6	37.5	38.7	38.6	38.2
20cm	35.2	36.1	37.2	38.1	38.8	39.2	39.3
30cm	36.2	36.3	36.4	36.6	36.9	37.1	37.4
50cm	36.9	36.9	36.9	36.8	36.7	36.6	36.5

Table 20-5. **Diurnal changes of air temp., water temp. and soil temp. of different soil layer**

DATE: JULY 25. 1986								
TIME	6:00	6:30	7:00	8:00	9:00	10:00	11:00	12:00
Air Temp.(°C)	28.7	29.2	31.0	36.1	40.0	43.0	43.5	43.0
Water Temp.(°C)	34.2	34.0	33.0	31.3	31.1	31.9	33.0	34.4
R.H. (%)	47	56	49	44	35	34	26	27
Evaporation(mm)		0.23		0.38	0.59	0.88	0.92	0.94
cont. 5cm	36.4	36.0	35.8	36.0	37.3	39.6	42.0	44.4
10cm	41.8	41.5	41.3	41.0	40.8	40.7	40.7	41.3
20cm	40.2	40.1	40.1	40.1	40.0	39.9	39.9	39.8
30cm	40.1	40.1	40.1	40.2	40.2	40.2	40.2	40.2
50cm	38.7	38.8	38.9	39.0	39.1	39.2	39.4	39.5
5L plot 5cm	30.5	31.7	30.3	29.9	31.0	33.5	36.1	38.0
10cm	34.0	33.6	33.5	33.0	33.1	33.8	35.4	37.3
20cm	36.1	36.0	35.7	35.5	35.2	35.0	35.1	35.5
30cm	37.7	37.6	37.5	37.4	37.3	37.1	37.0	36.9
50cm	38.1	38.1	38.1	38.3	38.4	38.4	38.4	38.3
10L plot 5cm	32.5	32.7	32.5	31.5	31.7	32.8	34.2	36.0
10cm	32.8	32.3	32.5	32.4	32.4	32.7	33.2	34.1
20cm	35.3	34.9	34.6	34.5	34.1	34.0	34.1	34.6
30cm	37.1	37.0	37.0	36.9	36.7	36.6	36.5	36.4
50cm	36.8	36.8	36.9	36.9	37.0	37.0	37.0	36.9

Table 20-6. Diurnal changes of air temp., water temp. and soil temp. of different soil layer

DATE: JULY 25, 1986							
TIME	13:00	14:00	15:00	16:00	17:00	18:00	19:00
Air Temp.(°C)	43.2	45.0	45.5	45.0	43.2	40.7	38.7
Water Temp.(°C)	35.0	37.4	38.0	38.0	37.0	36.0	34.2
R.H. (%)	27	23	25	23	24	37	41
Evaporation(mm)	1.14	1.20	1.16	1.58	1.12	1.10	1.10
cont. 5cm	46.8	49.2	50.7	52.0	51.5	50.8	49.4
10cm	42.0	43.0	43.9	44.8	45.5	46.0	46.2
20cm	39.8	39.8	39.9	40.0	40.0	40.1	40.3
30cm	40.1	40.0	40.0	40.0	39.8	39.8	39.8
50cm	39.5	39.5	39.5	39.5	39.4	39.2	39.0
5L plot 5cm	40.4	42.7	44.5	44.5	43.6	42.1	39.8
10cm	39.0	40.4	41.7	42.6	42.6	42.3	41.4
20cm	36.1	37.0	37.9	38.7	39.3	39.7	39.8
30cm	36.9	37.1	37.2	37.6	37.8	38.2	38.4
50cm	38.4	38.3	38.2	38.2	38.1	38.0	38.0
10L plot 5cm	38.1	39.9	41.1	41.6	41.2	40.5	39.5
10cm	35.2	36.8	38.0	36.4	36.1	35.8	36.2
20cm	35.3	36.2	37.1	38.0	38.6	39.0	39.1
30cm	36.4	36.5	36.6	36.7	37.0	37.3	37.5
50cm	36.9	37.0	36.9	36.9	36.8	36.7	36.6

Table 20-7. Diurnal changes of air temp., water temp. and soil temp. of different soil layer

DATE: Average of JULY 11, 18 and 25, 1986								
TIME	6:00	6:30	7:00	8:00	9:00	10:00	11:00	12:00
Air Temp.(°C)	25.4	26.4	29.5	34.4	38.2	41.5	42.7	43.7
Water Temp.(°C)	33.5	33.2	32.0	30.2	29.9	30.5	31.3	32.5
cont. 5cm	35.9	35.3	35.1	35.3	36.5	38.5	40.7	43.1
10cm	40.7	40.4	40.3	40.0	39.8	39.8	39.9	40.6
20cm	40.0	39.9	39.9	39.8	39.7	39.6	39.5	39.5
30cm	40.0	40.0	40.0	40.0	40.0	40.0	40.0	39.9
50cm	38.6	38.6	38.7	38.9	39.0	39.1	39.3	39.3
5L plot 5cm	30.1	31.1	30.0	29.5	30.4	32.9	35.9	38.3
10cm	33.4	32.9	32.9	32.3	32.2	33.1	35.0	37.0
20cm	36.0	35.8	35.5	35.3	34.9	34.7	34.8	35.2
30cm	37.7	37.6	37.5	37.4	37.2	37.0	36.9	36.8
50cm	38.0	38.0	38.1	38.3	38.3	38.3	38.3	38.3
10L plot 5cm	31.8	32.3	31.7	30.5	30.4	31.6	33.6	35.6
10cm	32.4	31.9	32.1	31.7	31.7	32.1	33.0	34.4
20cm	34.8	34.5	34.3	34.1	33.8	33.6	33.8	34.5
30cm	37.0	36.9	36.8	36.7	36.5	36.4	36.3	36.2
50cm	36.7	36.8	36.8	36.8	36.8	36.8	36.9	36.9

Table 20-8. Diurnal changes of air temp., water temp. and soil temp. of different soil layer

DATE: Average of JULY 11,18 and 25, 1986							
TIME	13:00	14:00	15:00	16:00	17:00	18:00	19:00
Air Temp.(°C)	44.2	44.7	45.1	44.4	42.7	40.6	38.1
Water Temp.(°C)	33.8	36.0	36.5	36.3	35.7	34.7	33.7
cont. 5cm	45.4	47.5	49.0	50.1	49.9	49.4	48.2
10cm	41.5	42.4	43.4	44.1	44.8	45.2	45.4
20cm	39.5	39.6	39.7	39.8	40.0	40.1	40.4
30cm	39.8	39.8	39.8	39.7	39.7	39.7	39.7
50cm	39.4	39.4	39.4	39.4	39.2	39.1	39.0
5L plot 5cm	40.3	41.9	43.6	44.0	43.5	42.1	40.0
10cm	39.0	40.4	41.8	42.6	42.8	42.4	41.5
20cm	35.9	36.8	37.8	38.6	39.3	39.7	39.8
30cm	36.8	36.9	37.1	37.5	37.8	38.1	38.4
50cm	38.3	38.2	38.1	38.1	38.0	38.0	38.0
10L plot 5cm	37.8	39.5	40.7	41.2	41.0	40.4	39.5
10cm	35.7	36.9	37.9	37.6	38.1	37.9	37.8
20cm	35.3	36.2	37.2	38.1	38.8	39.3	39.4
30cm	36.2	36.3	36.4	36.6	36.9	37.2	37.4
50cm	36.9	36.9	36.8	36.8	36.7	36.6	36.5

Table 20-9. Diurnal changes of air temp., water temp. and soil temp. of different soil layer

DATE: AUGUST 17, 1986								
TIME	6:00	6:30	7:00	8:00	9:00	10:00	11:00	12:00
Air Temp.(°C)	25.4	26.0	26.5	29.0	31.5	34.0	35.0	35.5
Water Temp.(°C)	32.0	30.5	29.0	27.1	27.0	27.4	28.3	29.7
R.H. (%)	73	75	74	65	58	52	48	46
Evaporation(mm)			0.19	0.23	0.14	0.40	0.46	0.47
cont. 5cm	36.2	35.7	35.5	35.2	36.0	37.6	39.9	42.3
10cm	42.6	42.4	42.2	41.7	41..4	41.4	41.3	41.4
20cm	40.8	40.6	40.6	40.6	40.5	40.4	40.3	40.3
30cm	40.0	40.0	40.0	40.1	40.1	40.2	40.2	40.3
50cm	39.0	39.0	39.0	39.1	39.2	39.4	39.5	39.6
5L plot 5cm	30.0	29.7	28.2	28.4	29.6	31.6	33.7	35.8
10cm	33.4	32.8	32.7	31.8	32.0	32.6	33.6	34.7
20cm	35.8	35.6	35.5	35.1	34.7	34.5	34.5	34.7
30cm	37.4	37.3	37.3	37.2	37.0	36.8	36.6	36.5
50cm	38.1	38.1	38.1	38.2	38.3	38.3	38.3	38.3
10L plot 5cm	32.2	31.2	30.8	30.2	30.4	31.4	32.5	34.0
10cm	32.0	31.1	31.3	31.0	31.2	31.8	32.2	32.8
20cm	34.2	34.0	33.8	33.3	32.9	32.8	32.8	33.0
30cm	36.3	36.2	36.2	36.0	35.9	35.7	35.5	35.5
50cm	36.5	36.4	36.4	36.4	36.5	36.6	36.6	36.6

Table 20-10. Diuranal changes of air temp., water temp. and soil temp. of different soil layer

DATE: AUGUST 17, 1986							
TIME	13:00	14:00	15:00	16:00	17:00	18:00	19:00
Air Temp.(°C)	37.0	38.0	38.5	38.5	38.5	37.0	35.0
Water Temp.(°C)	30.5	33.0	33.9	34.0	34.0	33.8	32.3
R.H. (%)	42	39	39	38	38	40	45
Evaporation(mm)	0.56	0.61	0.66	0.70	0.94	0.58	0.65
cont. 5cm	45.0	47.6	49.4	50.4	50.5	49.6	48.4
10cm	42.0	42.8	43.8	44.7	45.6	46.1	46.4
20cm	40.2	40.2	40.2	40.2	40.3	40.5	40.6
30cm	40.3	40.3	40.2	40.1	39.9	39.8	39.8
50cm	39.6	39.7	39.7	39.7	39.5	39.4	39.3
5L plot 5cm	38.3	40.8	42.4	42.5	41.3	39.9	38.0
10cm	36.0	37.8	39.4	40.3	40.4	40.1	39.5
20cm	35.3	36.1	37.0	37.7	38.4	38.6	38.8
30cm	36.5	36.7	36.9	37.1	37.4	37.6	37.8
50cm	38.3	38.3	38.2	38.2	38.0	38.0	38.0
10L plot 5cm	36.0	37.5	38.7	39.2	39.0	38.4	37.8
10cm	33.4	33.9	34.9	35.7	36.3	36.3	36.1
20cm	33.5	34.1	34.8	35.5	36.2	36.4	36.6
30cm	35.5	35.5	35.6	35.8	36.0	36.2	36.5
50cm	36.5	36.5	36.5	36.5	36.5	36.4	36.3

Table 20-11. Diurnal changes of air temp., water temp. and soil temp. of different soil layer

DATE: AUGUST 18, 1986								
TIME	6:00	6:30	7:00	8:00	9:00	10:00	11:00	12:00
Air Temp.(°C)	28.0	28.0	29.0	31.0	33.5	36.0	38.0	38.5
Water Temp.(°C)	32.9	31.2	29.9	28.1	28.0	28.4	29.3	30.7
R.H. (%)	64	64	59	55	49	44	37	37
Evaporation(mm)			0.27	0.39	0.40	0.66	0.74	0.62
cont. 5cm	36.3	36.1	35.8	35.6	36.2	37.6	39.8	42.1
10cm	42.4	42.3	42.1	41.7	41.4	41.3	41.3	41.4
20cm	40.6	40.6	40.5	40.4	40.3	40.3	40.2	40.1
30cm	40.0	40.0	40.0	40.0	40.0	40.1	40.1	40.2
50cm	38.9	39.0	39.0	39.1	39.2	39.3	39.5	39.5
5L plot 5cm	30.5	30.3	28.7	28.3	29.0	31.5	33.8	36.2
10cm	33.4	33.0	32.8	31.9	31.9	32.4	33.7	35.1
20cm	35.7	35.5	35.4	35.0	34.6	34.4	34.4	34.7
30cm	37.2	37.2	37.1	37.0	36.8	36.6	36.5	36.5
50cm	38.0	38.0	38.0	38.1	38.1	38.2	38.2	38.3
10L plot 5cm	32.4	31.9	31.3	30.5	30.5	31.4	32.9	34.7
10cm	32.1	31.6	31.6	31.3	31.2	30.6	32.1	32.8
20cm	34.0	34.0	33.6	33.3	32.9	32.7	32.9	33.2
30cm	36.2	36.2	36.0	35.9	35.7	35.6	35.5	35.5
50cm	36.4	36.4	36.3	36.5	36.5	36.5	36.6	36.5

Table 20-12. Diurnal changes of air temp., water temp. and soil temp. of different soil layer

DATE: AUGUST 18, 1986							
TIME	13:00	14:00	15:00	16:00	17:00	18:00	19:00
Air Temp.(°C)	39.0	39.8	40.5	40.0	40.0	38.2	37.0
Water Temp.(°C)	31.7	33.9	34.5	35.0	35.0	34.5	33.5
R.H. (%)	36	34	30	31	35	37	40
Evaporation(mm)	0.62	0.81	0.81	0.82	0.85	0.74	0.56
cont. 5cm	44.7	47.2	49.1	50.1	50.2	49.7	48.6
10cm	42.0	42.7	43.8	44.6	45.5	46.0	46.3
20cm	40.1	40.1	40.1	40.1	40.2	40.4	40.6
30cm	40.2	40.1	40.1	40.0	39.9	39.7	39.7
50cm	39.6	39.6	39.6	39.5	39.5	39.4	39.3
5L plot 5cm	38.6	40.7	42.5	43.0	42.0	40.5	38.5
10cm	36.6	38.4	39.9	40.8	41.0	40.7	39.9
20cm	35.3	36.1	37.1	37.8	38.4	38.8	39.0
30cm	36.5	36.6	36.9	37.0	37.4	37.6	37.9
50cm	38.2	38.1	38.1	38.0	38.0	38.0	37.9
10L plot 5cm	36.8	38.1	39.1	39.5	39.4	38.8	38.1
10cm	33.6	34.5	35.5	36.4	36.8	36.7	36.5
20cm	33.7	34.4	35.1	35.8	36.3	36.6	36.8
30cm	35.5	35.4	35.6	35.7	36.0	36.1	36.4
50cm	36.5	36.5	36.5	36.5	36.5	36.4	36.3

Table 20-13. **Diurnal changes of air temp., water temp. and soil temp. of different soil layer**

DATE: AUGUST 24, 1986								
TIME	6:00	6:30	7:00	8:00	9:00	10:00	11:00	12:00
Air Temp.(°C)	29.0	28.7	30.0	34.3	37.1	40.0	40.9	40.5
Water Temp.(°C)	33.2	31.7	30.9	29.4	29.0	29.7	30.7	31.9
R.H. (%)	47	54	51	42	34	29	29	28
Evaporation(mm)			0.28	0.39	0.57	0.85	0.73	0.77
cont. 5cm	36.1	35.7	35.5	35.5	36.3	38.2	40.5	43.1
10cm	42.7	42.3	42.2	41.8	41.6	41.5	41.5	41.7
20cm	40.6	40.6	40.6	40.5	40.4	40.4	40.3	40.2
30cm	39.8	39.8	39.9	40.0	40.0	40.1	40.2	40.2
50cm	38.6	38.6	38.7	38.8	38.9	39.1	39.2	39.3
5L plot 5cm	30.4	31.3	29.7	28.7	29.7	32.9	35.6	38.1
10cm	33.6	33.2	33.3	32.5	32.4	33.0	34.4	36.0
20cm	35.8	35.6	35.5	35.2	34.8	34.6	34.6	35.0
30cm	37.4	37.2	37.2	37.0	36.9	36.7	36.6	36.5
50cm	38.0	37.8	38.0	38.1	38.1	38.1	38.2	38.2
10L plot 5cm	32.0	32.0	31.5	30.6	30.4	31.2	32.4	34.1
10cm	32.1	31.7	31.7	31.5	31.3	31.8	32.3	33.1
20cm	34.0	33.8	33.6	33.3	33.0	32.9	33.0	33.3
30cm	36.0	36.0	36.0	35.8	35.6	35.5	35.4	35.3
50cm	36.2	36.2	36.2	36.3	36.5	36.5	36.5	36.5

Table 20-14. Diurnal changes of air temp., water temp. and soil temp. of different soil layer

DATE: AUGUST 24, 1986							
TIME	13:00	14:00	15:00	16:00	17:00	18:00	19:00
Air Temp.(°C)	41.5	42.0	42.4	42.3	41.3	40.0	38.0
Water Temp.(°C)	32.0	33.9	34.6	35.0	35.0	34.2	33.0
R.H. (%)	26	26	22	22	24	26	27
Evaporation(mm)	1.02	0.84	1.15	1.22	0.96	1.21	1.01
cont. 5cm	46.2	48.5	50.5	51.5	51.5	50.8	49.3
10cm	42.5	43.3	44.4	45.4	46.0	46.5	46.7
20cm	40.1	40.1	40.1	40.2	40.3	40.4	40.6
30cm	40.0	40.0	40.0	39.9	39.8	39.6	39.6
50cm	39.3	39.3	39.3	39.3	39.2	39.0	39.0
5L plot 5cm	40.5	41.2	42.6	42.9	42.3	40.7	38.8
10cm	37.4	39.1	40.7	41.4	41.5	41.1	40.3
20cm	35.7	36.5	37.5	38.4	38.7	39.1	39.2
30cm	36.6	36.7	37.0	37.3	37.5	37.7	38.0
50cm	38.1	38.1	38.0	38.0	37.9	37.8	37.8
10L plot 5cm	36.3	37.3	38.5	38.9	39.0	38.6	38.0
10cm	32.9	34.6	35.7	36.6	37.0	37.1	36.8
20cm	33.9	34.4	35.1	35.8	36.2	36.5	36.6
30cm	35.3	35.3	35.5	35.6	35.8	36.1	36.3
50cm	36.4	36.4	36.4	36.5	36.4	36.3	36.2

Table 20-15. Diurnal changes of air temp., water temp. and soil temp. of different soil layer

DATE: Average of AUGUST 17,18 and 24, 1986								
TIME	6:00	6:30	7:00	8:00	9:00	10:00	11:00	12:00
Air Temp.(°C)	27.5	27.6	28.5	31.4	34.0	36.7	38.0	38.2
Water Temp.(°C)	32.7	31.1	29.9	28.2	28.0	28.5	29.4	30.8
cont. 5cm	36.2	35.8	35.6	35.4	36.2	37.8	40.1	42.5
10cm	42.6	42.3	42.2	41.7	41.5	41.4	41.4	41.5
20cm	40.7	40.6	40.6	40.5	40.4	40.4	40.3	40.2
30cm	39.9	39.9	40.0	40.0	40.0	40.1	40.2	40.2
50cm	38.8	38.9	38.9	39.0	39.1	39.3	39.4	39.5
5L plot 5cm	30.3	31.4	28.9	28.5	29.4	32.0	34.4	36.7
10cm	33.5	33.0	32.9	32.1	32.1	32.7	33.6	35.3
20cm	35.8	35.6	35.5	35.1	34.7	34.5	34.5	34.8
30cm	37.3	37.2	37.2	37.1	36.9	36.7	36.6	36.5
50cm	38.0	38.0	38.0	38.1	38.2	38.2	38.2	38.3
10L plot 5cm	32.2	31.7	31.2	30.4	30.4	31.4	32.6	34.3
10cm	32.1	31.5	31.5	31.3	31.2	31.4	32.2	32.9
20cm	34.1	33.9	33.7	33.3	32.9	32.8	32.9	33.2
30cm	36.2	36.1	36.1	35.9	35.7	35.6	35.5	35.4
50cm	36.4	36.3	36.3	36.4	36.5	36.5	36.6	36.5

Table 20-16. Diurnal changes of air temp., water temp. and soil temp. of different soil layer

DATE: Average of AUGUST 17, 18 and 24, 1986							
TIME	13:00	14:00	15:00	16:00	17:00	18:00	19:00
Air Temp.(°C)	39.2	39.9	40.5	40.3	39.9	38.4	36.7
Water Temp.(°C)	31.4	33.6	34.3	34.7	34.7	34.2	32.9
cont. 5cm	45.3	47.8	49.7	50.7	50.7	50.0	48.8
10cm	42.2	42.9	44.0	44.9	45.7	46.2	46.5
20cm	40.1	40.1	40.1	40.2	40.3	40.4	40.6
30cm	40.2	40.1	40.1	40.0	39.9	39.7	39.7
50cm	39.5	39.5	39.5	39.5	39.4	39.3	39.2
5L plot 5cm	39.1	40.9	42.5	42.8	41.9	40.4	38.4
10cm	36.7	38.4	40.0	40.8	41.0	40.6	39.9
20cm	35.4	36.2	37.2	38.0	38.5	38.8	39.0
30cm	36.5	36.7	36.9	37.1	37.4	37.6	37.9
50cm	38.2	38.2	38.1	38.1	38.0	37.9	37.9
10L plot 5cm	36.4	37.6	38.8	39.2	39.1	38.6	38.0
10cm	33.3	34.3	35.4	36.2	36.7	36.7	36.5
20cm	33.7	34.3	35.0	35.7	36.2	36.5	36.7
30cm	35.4	35.4	35.6	35.7	35.9	36.1	36.4
50cm	36.5	36.5	36.5	36.5	36.5	36.4	36.3

Table 21. The growth of Samar, Ghaff and Arak in Al Wagon (May to August, 1986)

Species		May 22	June 24	July 24	August 25
Samar (Acasia tortilis)	Height(cm)	38 ± 12 (100)	48 ± 15 (126)	57 ± 13 (150)	65 ± 18 (171)
	Diameter(mm)	-	5.0 ± 1.1	5.0 ± 1.2	5.8 ± 1.2
Ghaff (Prosopis spicigera)	Height(cm)	41 ± 7 (100)	46 ± 9 (112)	52 ± 6 (127)	60 ± 9 (146)
	Diameter(mm)	-	4.9 ± 1.0	4.5 ± 1.0	5.5 ± 1.4
Arak (Salvadora persica)	Height(cm)	56 ± 16 (100)	59 ± 17 (105)	69 ± 15 (123)	82 ± 17 (146)
	Diameter(mm)	-	6.2 ± 1.3	5.0 ± 1.2	7.2 ± 1.9

Table 22. Changes of moisture in soil samples from different layers in Al Wagon (June to August, 1986)

Plot	Depth of soil layer (cm)	June 3	June 24	July 24	August 25
1	0-1	10.6	9.0	1.3	0.9
	1-10	13.4	12.6	9.8	9.1
	10-30	12.5	13.5	10.0	10.1
	30-50	11.4	13.7	9.0	8.0
	50-70	9.0	8.7	8.7	6.7
	70-100	8.8	6.6	6.7	5.9
2	0-1	9.9	9.6	0.8	1.5
	1-10	10.3	12.3	6.3	9.6
	10-30	12.2	12.1	11.1	13.0
	30-50	12.2	10.8	14.4	12.1
	50-70	10.1	8.3	9.9	11.3
	70-100	6.0	5.8	8.9	10.7
3	0-1	11.2	12.6	4.7	4.3
	1-10	16.1	16.4	15.1	10.5
	10-30	19.5	15.6	22.8	21.0
	30-50	21.5	26.4	24.4	24.7
	50-70	23.3	25.2	24.0	22.5
	70-100	26.2	24.6	24.0	22.3

Table 23. Changes of pH and EC* in saturation extracts of soil samples from different layers in Al Wagon (June to August, 1986)

Plot	Depth (cm)	June 3 pH	June 3 EC	June 24 pH	June 24 EC	July 24 pH	July 24 EC	August 25 pH	August 25 EC
1	0-1	8.1	129.6	7.9	170.2	7.8	138.2	7.6	34.5
	1-10	7.9	19.2	8.0	13.1	7.9	11.6	7.4	8.9
	10-30	8.1	10.5	8.1	5.7	8.1	4.9	7.4	8.8
	30-50	8.3	7.1	8.0	7.8	8.1	5.1	7.7	6.2
	50-70	8.0	6.7	8.0	5.3	8.1	4.2	8.2	4.7
	70-100	8.0	6.6	8.1	4.5	8.0	4.6	8.0	4.7
2	0-1	7.8	167.3	7.6	188.6	7.5	38.2		
	1-10	7.8	39.9	7.7	24.3	8.0	5.7		
	10-30	7.9	11.0	7.9	10.2	8.1	7.0		
	30-50	8.1	8.4	8.0	5.9	8.1	7.2		
	50-70	8.2	7.2	8.1	4.7	8.1	6.0		
	70-100	8.3	4.6	7.9	4.9	8.1	4.5		
3	0-1	7.8	162.9	7.1	57.6	7.8	139.2		
	1-10	7.9	18.8	7.2	10.7	7.3	10.7		
	10-30	8.3	8.6	7.3	9.2	8.0	9.2		
	30-50	8.3	7.5	7.2	9.0	7.4	7.6		
	50-70	8.1	9.1	7.2	9.0	7.3	7.6		
	70-100	8.0	7.3	7.2	7.1	7.3	6.7		

* mS／cm

6. Study on the dormancy breaking of some local tree seeds in UAE (Theme C)

Abstract

The effective treatment to break the seed dormancy of some local tree seeds was studied. Six kinds of treatment of dormancy breaking were discussed.

The following results were obtained:

(1) *Acacia tortilis* (Samar) : Treatments of concentrated H_2SO_4 and hot water (80°C, 10 min) were effective, and their germination percentage after 30 days were 81% and 71%, respectively.

(2) *Acacia arabica* (Garaat) : There was not so much difference in germination percentage among the treatments. The germination percentage was relatively high in all treatments.

(3) *Prosopis spicigera* (Ghaff): Treatments of concentrated H_2SO_4 and hot water (80°C, 10 min) were effective, and their germination percentage after 30 days were 57% and 52%, respectively.

(4) *Prosopis juliflora* (Ghwaif): Treatments of concentrated H_2SO_4 and hot water (80°C and 60°C, 10 min) were effective, and their germination percentage after 30 days were 100%, 91% and 80/, respectively.

(5) *Zizyphus spina-christ* (Sidar) : Treatment of soaking in water for three days was the most effective, and its germination percentage after 30 days was 47%.

It is well-known that most of leguminous tree seeds exhibit some degree of dormancy, and they will not germinate promptly even when placed under the most favorable environment conditions[1]. And there are many methods of dormancy breaking; for example, hot water treatment, various chemical treatment, and so on.

This study was carried out in order to get the most effective treatment to break the seed dormancy of some local tree seeds in UAE.

Materials and Methods

Seeds of *Prosopis juliflora* were collected at Hilli Garden on 21 December 1985. Other four kinds of tree seeds, *Acacia tortilis, Acacia arabica, Prosopis spicigera* and *Zyzyphus spina-christ* were provided by Department of Agriculture of Al Ain Municipality. Seeds were treated before sowing, and one hundred of seeds were used in each treatment.

Treatments are as follows:

(1) Control: No treatment.

(2) Scarifying: Seeds were scarified on their surface by the scarifier containing sand and small ceramic balls (approximately 7 mm in diameter) for 2 hours.

(3) Soaking in concentrated H_2SO_4 : Seeds were soaked in concentrated sulfuric acid (98%) for 20 minutes.

(4) Soaking in water: Seeds were soaked in tap water for 3 days.

(5) Soaking in hot water at 60°C: Seeds were soaked in hot water at 60°C for 10 minutes.

(6) Soaking in hot water at 80°C: Seeds were soaked in hot water at 80°C for 10 minutes.

Treated seeds of *Prosopis juliflora* were planted in black plastic bags (20cm in diameter and 20cm in height) on 15 March 1986. Other four kinds of seeds were planted in same plastic bags on 12 May 1986. Each plastic bag contained approximately 6kg of air-dried sandy soil and approximately 600g (2 litre) of potting soil. Ten seeds per pot were planted, and ten replicates were prepared for each treatment. The number of germination in each treatment was counted daily.

Results and Discussion

The results are shown in Table 25 and Fig. 11, 12, 13, 14 and 15. According to the results, it is recognized that the following treatments are effective to each local tree seeds.

(1) *Acacia tortilis* (Samar)
Treatments of concentrated H_2SO_4 and hot water (80°C,10min) were effective to this seed. Their germination percentage after 30 days from sowing was 81% and 71%, respectively. In contrast, germination percentage of untreated seeds was only 37%. There is significant difference among these treatments at the 5% level (See Table 25).

(2) *Acacia arabica* (Garrat)
There was no significant difference in germination percentage among the treatments. The germination percentage was relatively high in all treatments. The germination percentage was ranged from 57% to 69%.

(3) *Prosopis spicigera* (Ghaff)
Treatments of concentrated H_2SO_4 and hot water (80°C, 10 min) were effective. Their germination percentage after 30 days from sowing was 57% and 52%, respectively. In contrast, 34% of untreated seeds germinated after 30 days.

(4) *Prosopis juliflora* (Ghwaif)
Only 27% of untreated seeds germinated after 30 days. In contrast, 100% of treated seeds germinated in concentrated H_2SO_4 treatment after only 7 days, and it was the most effective treatment to break the dormancy of this seed in all treatment. The treatment of soaking in hot water at 80°C and 60°C were also effective in dormancy breaking, and their germination percentage after 30 days were 91% and 80%.

(5) *Zizyphus spina-christ* (Sidar)
The treatment of soaking in tap water for three days was the most effective, and 47% of

treated seeds was germinated after 30 days by this treatment. In contrast, only 8% of untreated seeds germinated after 30 days.

Literature cited

(1) Kramer, P.J. and Kozlowski, T.T., Physiology of Woody Plants, 515–523 (1979).

Table 25. Germination percentage in each treatment

Treatment	Acacia tortilis	Acacia arabica	Prosopis spicigera	Prosopis juliflora	Zizyphus spina-christ
cont.	37 a	61 a	34 a	27 a	8 a
scari.	45 a	57 a	32 a	36 a	15 a
H_2SO_4	81 c	63 a	57 b	100 d	11 a
soaking	49 a	58 a	31 a	30 a	47 b
60°C	55 b	57 a	28 a	80 b	8 a
80°C	71 c	69 a	52 b	91 c	9 a

Germination Percentage in rows followed by the same letters are not signifficantly different at the 5% level

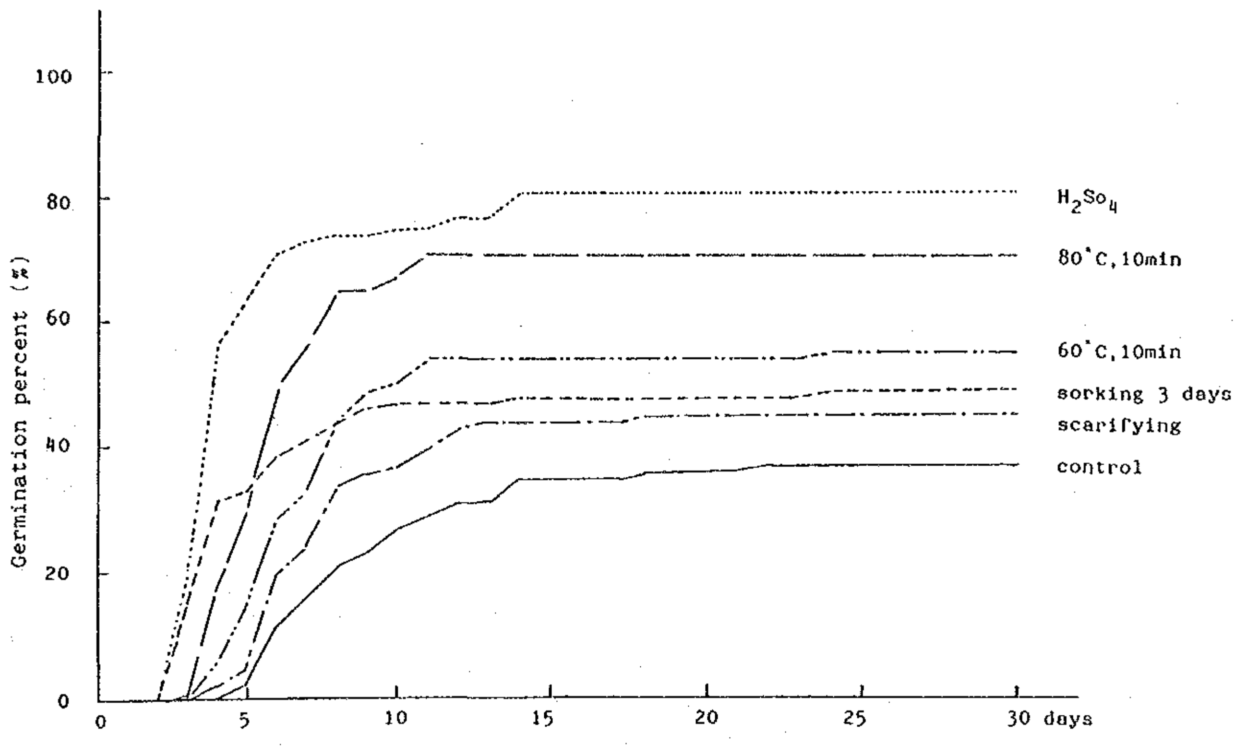

Fig. 11. Germination percentage curve of *Acacia tortilis*

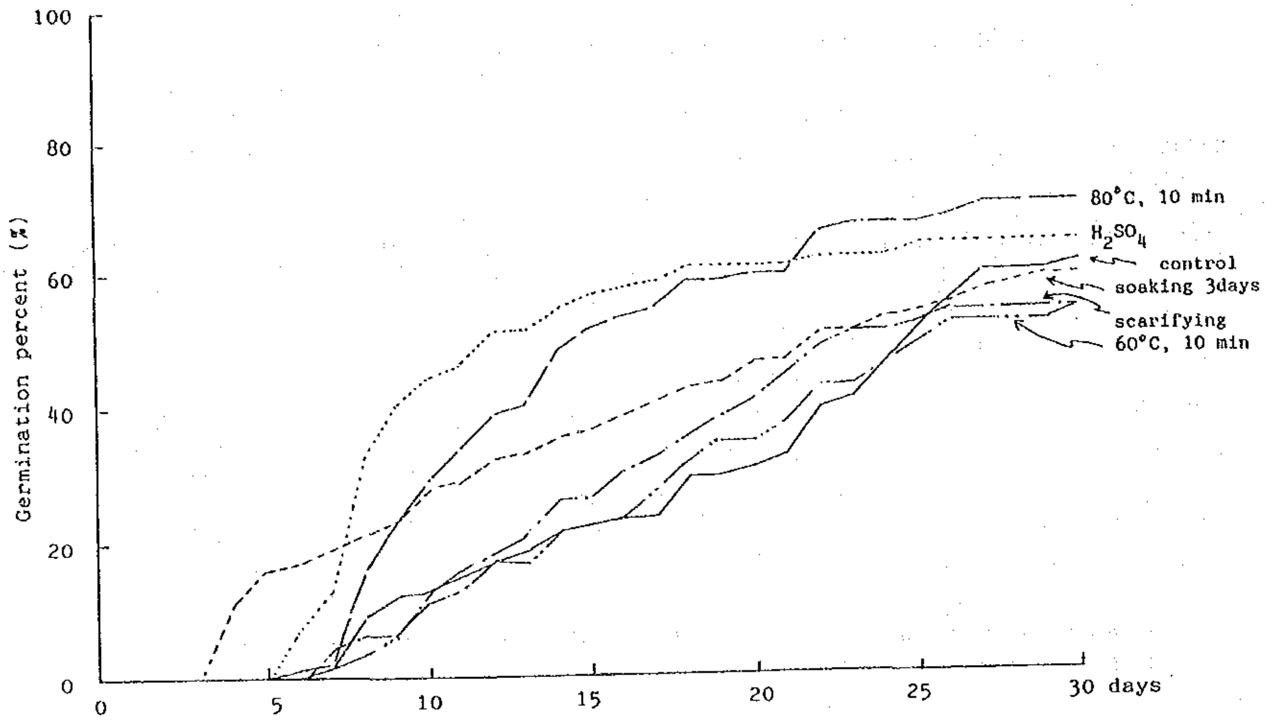

Fig. 12. Germination percentage curve of *Acacia arabica*

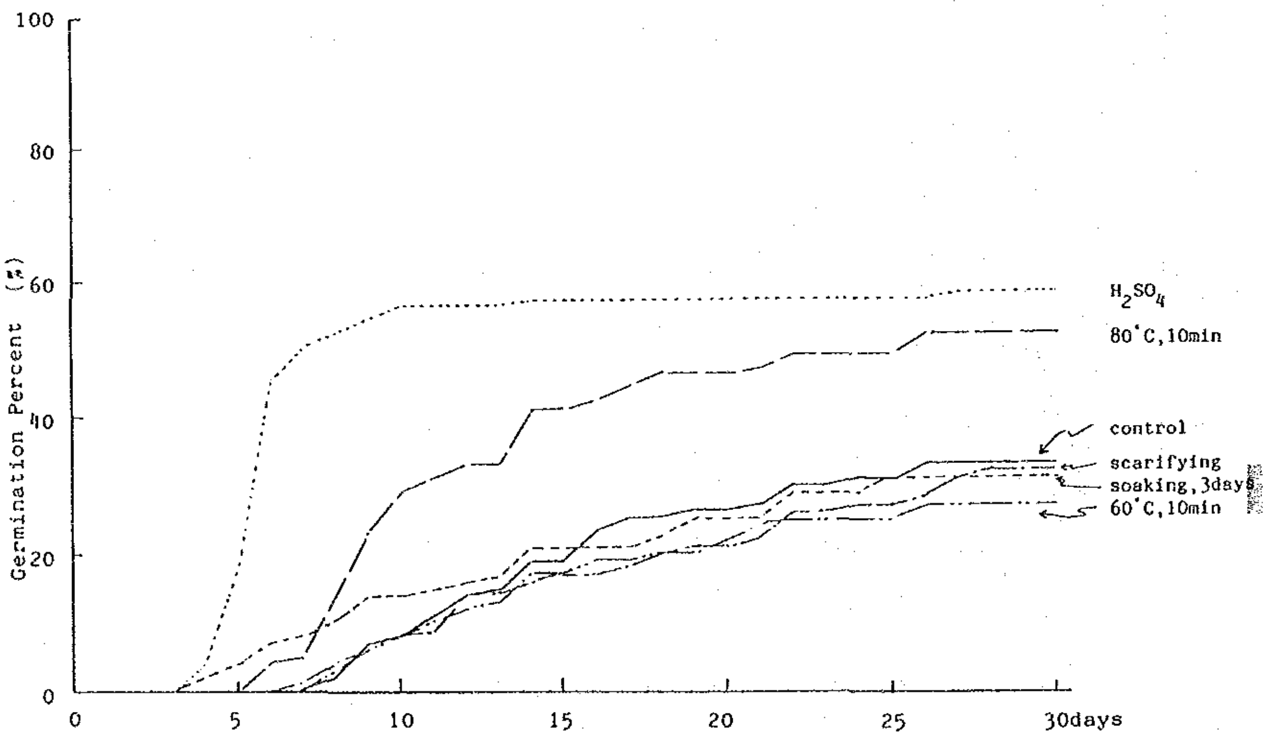

Fig. 13. Germination percentage curve of *Prosopis spicigera*

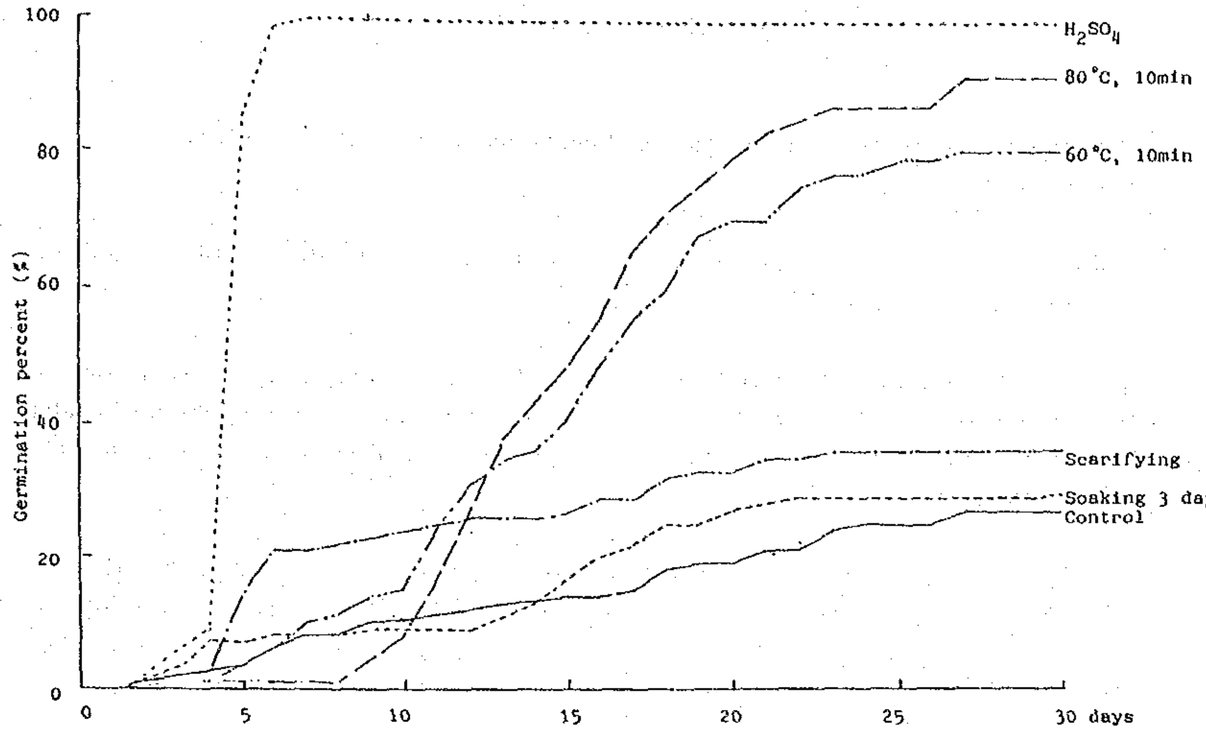

Fig. 14. Germination percentage curve of *Prosopis juliflora*

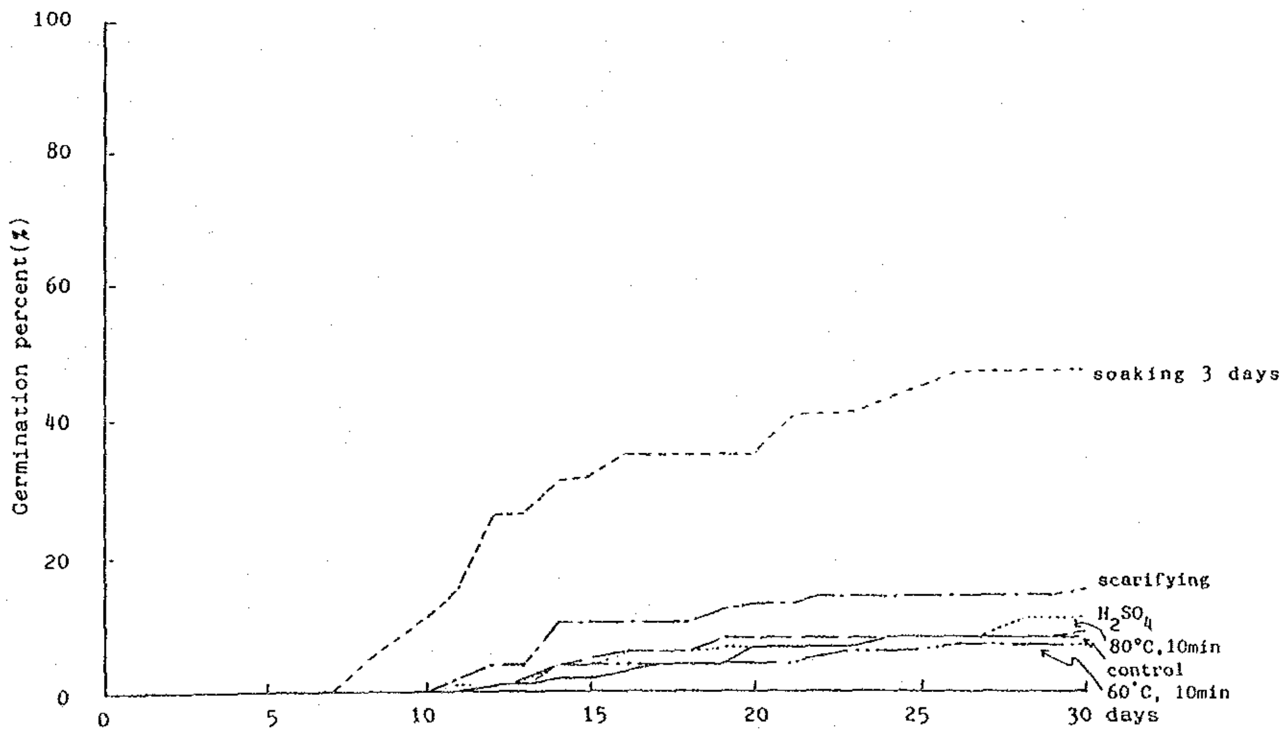

Fig. 15. Germination percentage curve of Zizyphus spina-christ