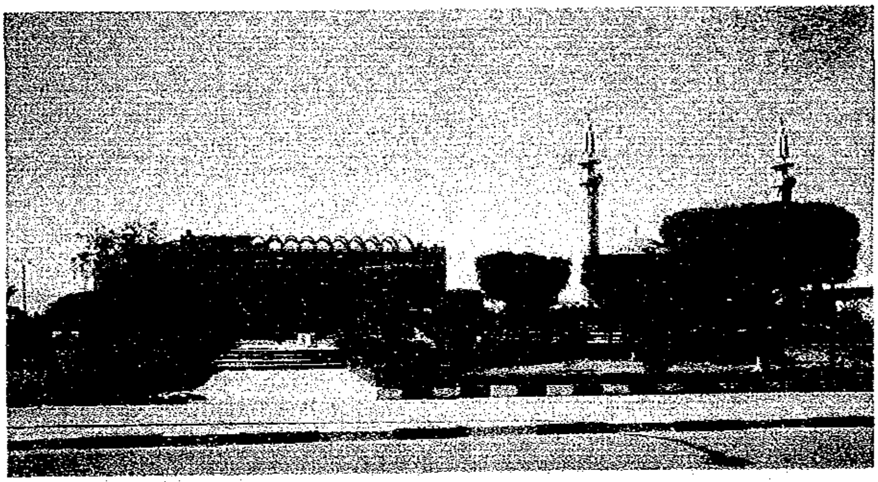
The Annual Report of the Joint Study Project on Improvement of Arid Land Agriculture in UNITED ARAB EMIRATES

(September, 1986~August, 1987)



March, 1988

The Japan International Cooperation Agency

[cover print]

Building of Administration Bureau, UAE University

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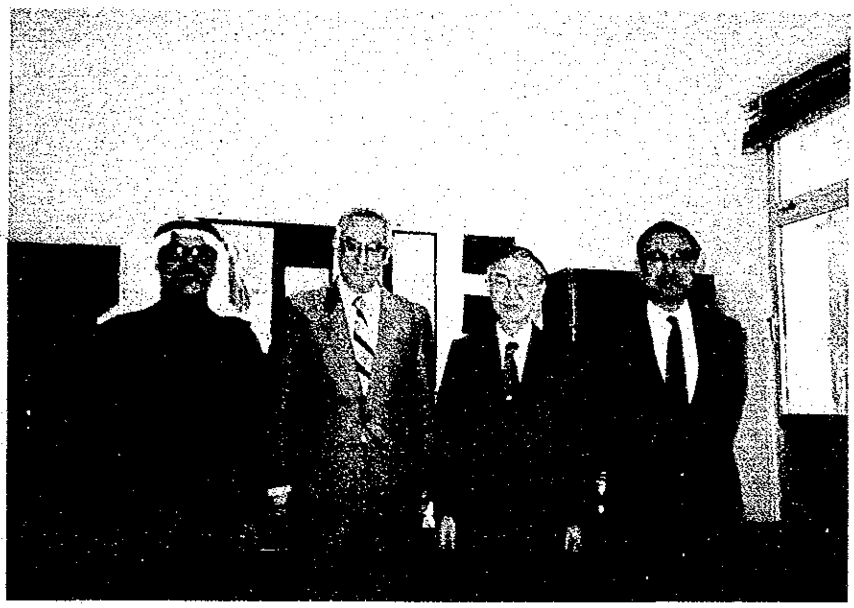
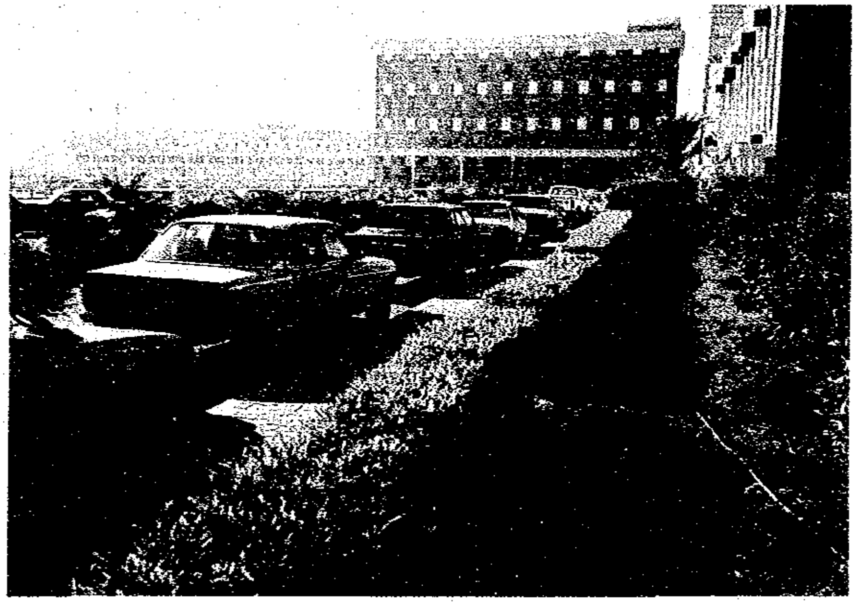
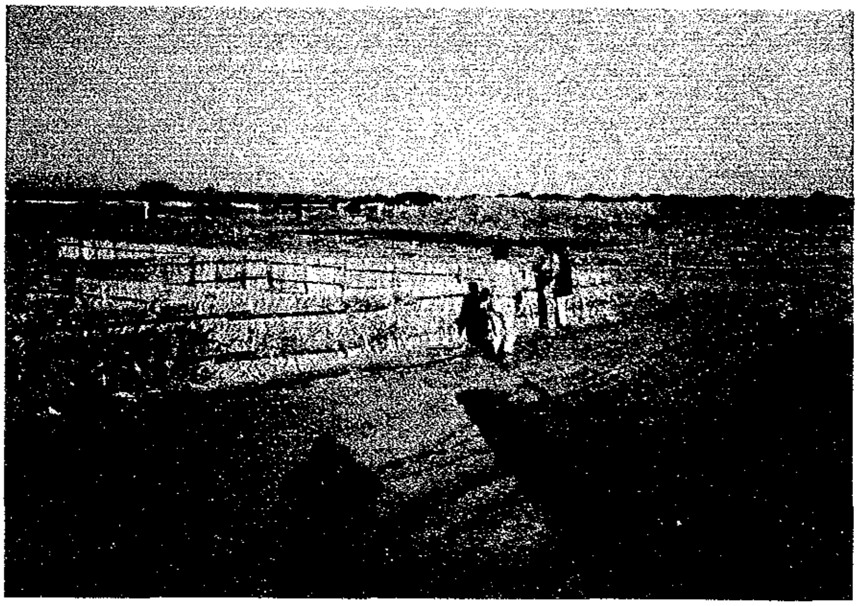


Staff members of the Joint Study Project at the Dean room, Faculty of Agriculture, UAE University. Dr. Al Afifi, Dr. Saghir (Dean), Dr. Matsuda and Dr. Murai (from left side).



Buildings of Faculty of Agriculture, UAE University.

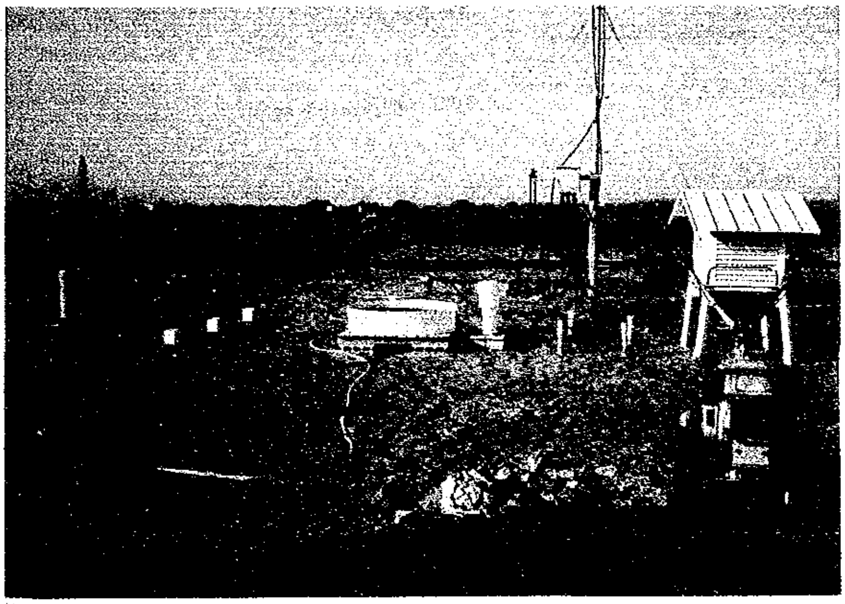
Staff members of the Project at theme B field, the Experimental Farm.
Mr. Onuma, Dr. Murai, Dr. Masoum, Dr. Ibrahim, Mr. Koto and Dr. Matsuda (from left side).



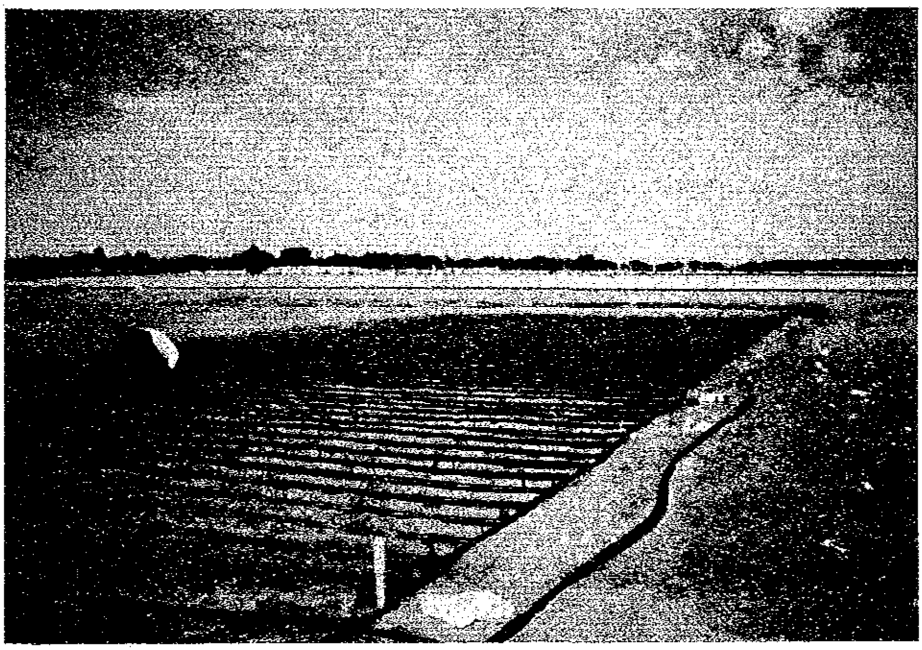
Artificial sand dune, experiments on the mulching agents and on the dates fronds sand fence of different kinds of density at theme A field.

Experiment on the dates fronds sand fence of different kinds of density (theme A).

Staff members surveying the growth of Samar in the experiment on the sand fence.
Dr. Murai, Mr. Yoshizaki, Dr. Matsuda and Dr. Ibrahim (from left side).

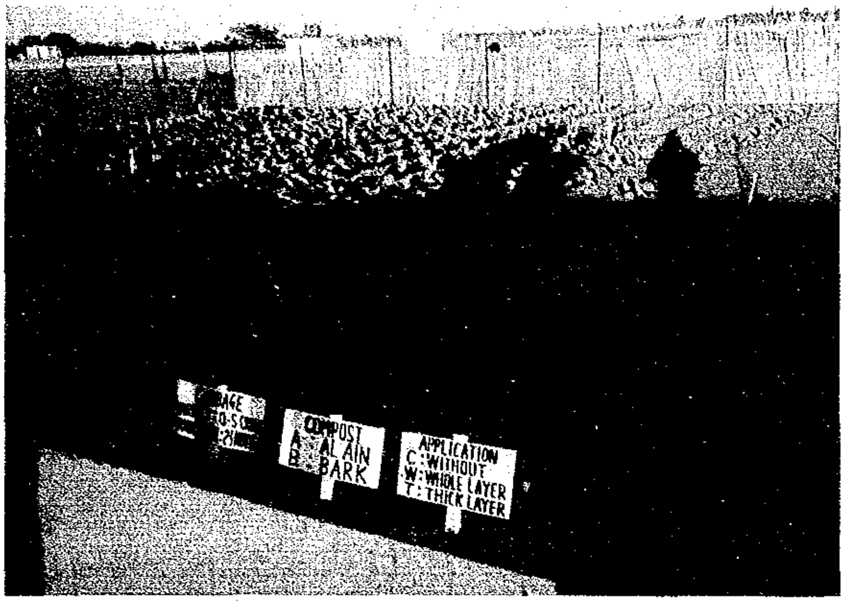


Meteorological station at the Project field.



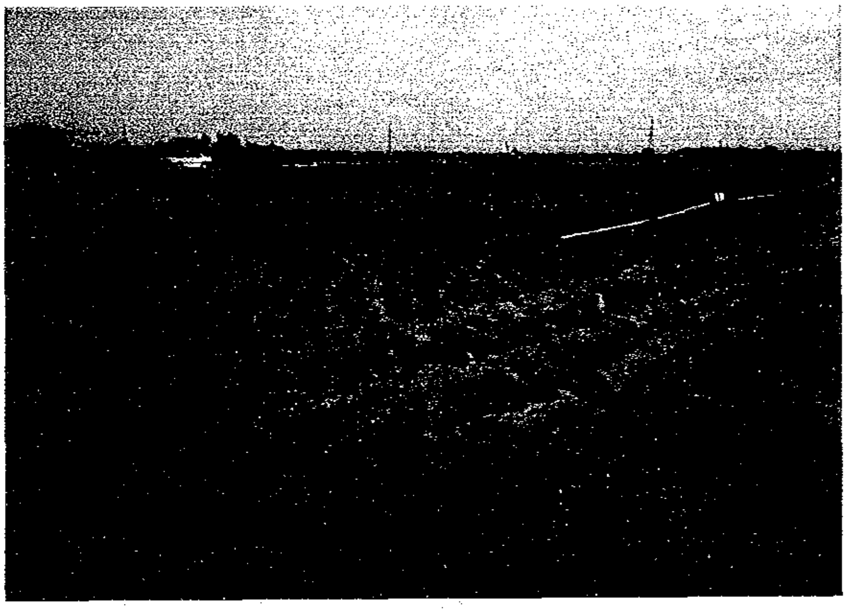
Experiment on the effect of compost layer on the yield of wheat (theme B).

Experiment on the effect of compost layer on the yield of alfalfa (theme B).



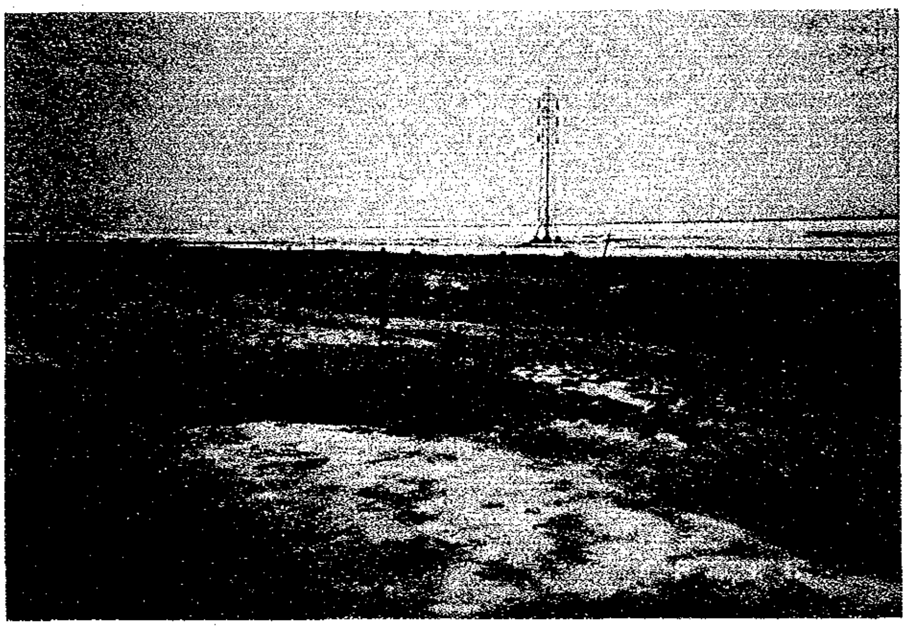
Experiment on the effect of two kinds of compost layer on the yield of cabbage (theme B).

Experiment on the effect of compost layer on the yield of spinach irrigated with saline water (theme B).



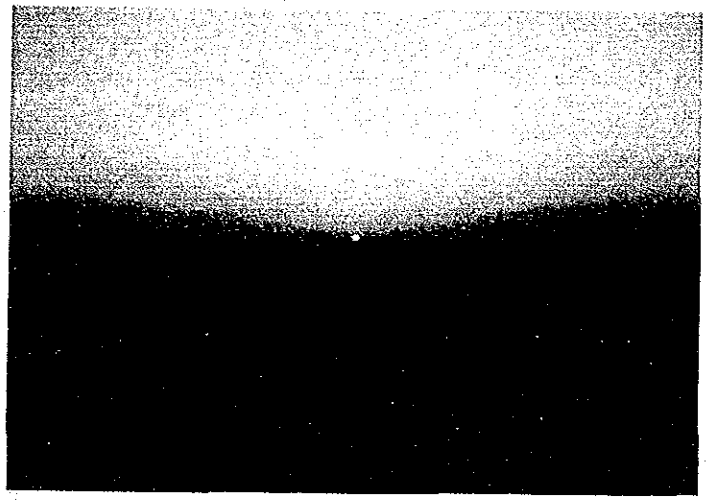
Experiment on the growth analysis of alfalfa (theme B).

Staff members of Japanese study team showing honor to the President and the staffs of UAE University at the reception.

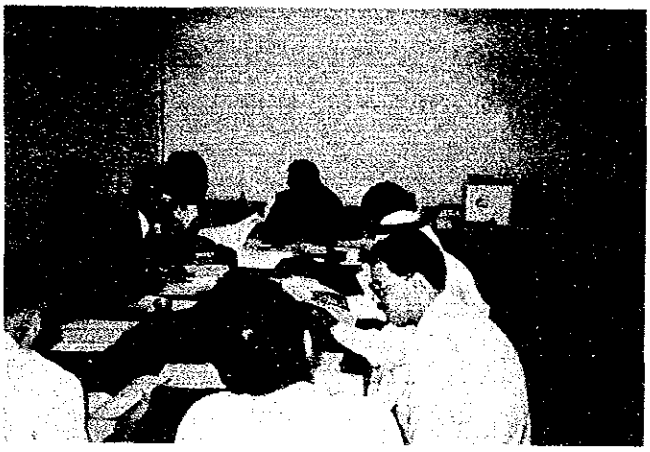


Salts accumulated at desert soil surface near Abu Dhabi after raining.

Desert seen from Mt. Hafit in the vicinity of Al Ain.

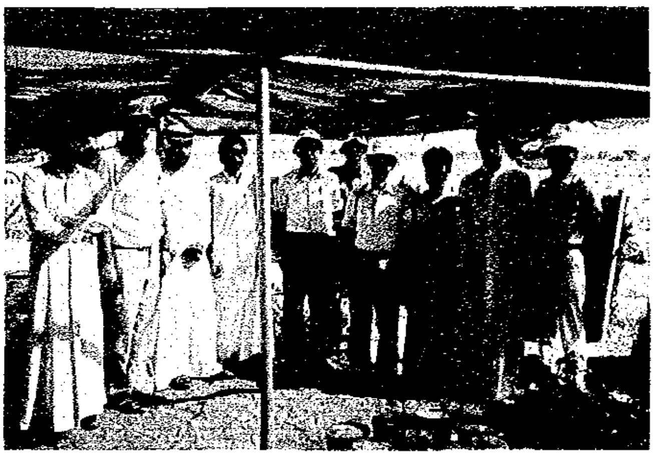


Sunset seen from the Experimental Farm.



Meeting on the Joint Study Project at the meeting room, Faculty of Agriculture, UAE University.

Staff members of the Project in the front of the artificial sand dune. Mr. Itany, Dr. Al Afifi, Dr. Matsuda, Dr. Saghir, Mr. Yoshizaki and Dr. Murai (from left side).



Staff members of the Project and students of Faculty of Agriculture at the nursery, Experimental Farm.

CONTENTS

I. PREFACE

On the basis of the agreement signed between the UAE University and the Japan International Cooperation Agency (JICA), the Joint Study Project on the improvement of arid land agriculture in the United Arab Emirates (UAE) was initiated since September 1985 by both Faculties of Agriculture, UAE and Shizuoka Universities.

Three long-term experts and thirteen short-term experts from JICA were dispatched to UAE University according to the agreement by August 1987. Draft plans for implementation of the project were discussed by study teams from both Universities, and then the master plan as mentioned below had been agreed.

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 B-1 :	Studies on the effects of a subsurface compost layer on water preservation, salinity and yields of crops in sandy soil
Theme B-2 :	Studies on cultivation methods in UAE
Theme C :	Studies on introduction and breeding of well-known drought- and salt-tolelant crops in UAE

In accordance with the master plan, Project teams conducted preliminary experiments and surveys at the Experimental Farm, Al Oha and its vicinity. The results obtained during the first year were reported in the Annual Report of the Joint Study Projct (September, 1985 – August, 1986)[1] by JICA.

The construction of facilities such as artificial sand dune and irrigation system for the Project was established by the endeavor of UAE University in the beginning of the second year. Project teams accordingly started experiments on each theme at the Experimental Farm.

On the other hand, Dean A.R. Saghir, Dr. M. Al Afifi and Mr. S. Itani, counterparts from the Faculty of Agriculture, UAE University visited some Universities and Agriculture Research Institutes, Ministry of Agriculture, Forestry and Fishery in Japan, for observation and research works on the arid land agriculture during the second year.

The equipments and materials necessary for the project were continually sent to UAE University from JICA after the first year of the Project.

The results obtained through the experiments conducted by Project teams in the second year are described in this Annual Report.

Reference

1) The Japan International Cooperation Agency, 1987 : The Annual Report of the Joint Study Project on Improvement of Arid Land Agriculture in UNITED ARAB EMIRATES (September, 1985 – August, 1986), pp. 1 – 96

II. MASTER PLAN OF THE JOINT STUDY PROJECT

1. Background and Objectives

The high temperature, drought, scarce 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 research.

The joint study project is aimed at improvement and development of agriculture in arid lands through basic research under the main theme "Studies on the development of agriculture by fixation of sand dunes 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.

2. Progress of the Joint Study Project

The outline of experimental plots for each theme is shown in Fig. 1, 2 and 3, time schedule is shown in Table 1. Followings are the progress of the experiments and investigations on each theme.

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

(1) Experiment on fixation of sand dune

Construction of artificial sand dunes have been completed during phase 1. Sand fence has been constructed on the top of the artificial sand dune and observation of topographical changes and shifting sand was carried out in phase 2. Same observation for natural sand dunes was also carried out. Tree plantation and mulching treatment on the artificial sand dune and further observation shall be continued in the following phases.

(2) Effect of different densities of date fronds mat fence

Date fronds mat fence has been constructed in different densities by February 1987. Local trees (Samar and Ghaff) were planted on April 1987. Tree growth and amount sand shifting were observed periodically during phase 2. This experiment shall be continued in the following phases.

(3) Effect of mulching and water holding materials on tree growth

This experiment shall be started in phase 3.

(4) Effect on different materials of sand fence

This experiment shall be started when the materials will be available.

(5) Others

1) Investigation of afforestation site

Periodical observation of tree growth and soil characteristics was carried out since June 1986 at Al Wagon afforestation site and shall be continued in the following phases. Growth of windbreak trees around the Experimental Farm has also been observed during one year starting October 1986.

2) Monthly tree planting

Samar and Ghaff have been planted every month between June 1986 and June 1987 in order to understand the best transplanting season. Growth of trees was observed during phase 2 and shall be continued.

3) Different irrigation levels trial

Growth of local trees under different irrigation levels was observed for one year starting May 1986.

4) Chemical mulching durability

Preliminary experiments using several chemical mulching treatments have been carried out since October 1986. Durability of each treatment was observed and compared.

5) Preliminary survey on remote sensing

Two different scenes of different bands were obtained for various analyses such as environmental changes and desert greening activities.

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

(1) Effect of thick layer of bark compost on :

1) Growth of Squash

This experiment had been carried out at Agricultural Experimental Station, Kuwaitat from September to December 1986.

2) Growth of Wheat

This experiment had been carried out during winter season 1986/1987. Residual effect of the compost applied shall be studied in the following phase.

3) Growth of Alfalfa

Alfalfa has been planted since December 1986 to study the effect of compost on growth and shall be continued to study the residual effect.

(2) Effect of compost layer under saline water irrigation on :

1) Salt accumulation

This small scale pot experiment had been carried out in phase 1. Soil samples were analyzed in phase 2 and the results are summarized in this report.

2) Growth of Spinach

This experiment shall be carried out in phase 3.

(3) Comparison of different kinds of compost on vegetable growth

This experiment shall be carried out in the next phase.

Theme B-2 : Studies on cultivation methods in UAE

(1) Growth analysis of Wheat and Alfalfa

Growth analysis and productive structure have been studied for wheat during winter season of 1986/1987. This will be repeated in the next season. The same study has been done for alfalfa since December 1986.

(2) Effect of cultivation methods on microclimate and plant growth

Alfalfa has been planted under the different irrigation levels and diurnal changes in soil temperature and moisture were observed. Detailed observations will be started in the next phase.

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

(1) Variety test

Tree seeds collected were sown in the nursery and some seedings are ready for planting to test for drought and salt tolerance. Comparison tests for some varieties of Cucumber, Okra and Alfalfa have also been carried out.

(2) Screening tests for the seeds collected

This experiment shall be started in phase 3 by using the Growth Chamber (Biotron).

3. **Project Team**

The project is being implemented jointly by UAE University Team and the Japanese Team. Each team consists of the following experts :

(1) THE UAE STUDY TEAM

Dr. Abdur-Rahman Saghir, Team Leader, Dean Faculty of Agriculture

Dr. Mahmoud A. Al Afifi, Chairman of crop production

Dr. Abul Hassan S. Ibrahim, Agronomy
Dr. Ahmed A. Hassan, Horticulture
Dr. Ahmed A. Almasoum, Horticulture
Mr. Suhayl A. Itani, Soil and irrigation

(2) THE JAPANESE STUDY TEM
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, Silviculture
Mr. Hiromi Yokota, Plant Nutrition
Mr. Akira Koto, Soil Science
Mr. Shinji Yoshizaki, Silviculture
Mr. Hiroyasu Onuma, Plant Nutribution

4. Project Phases

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

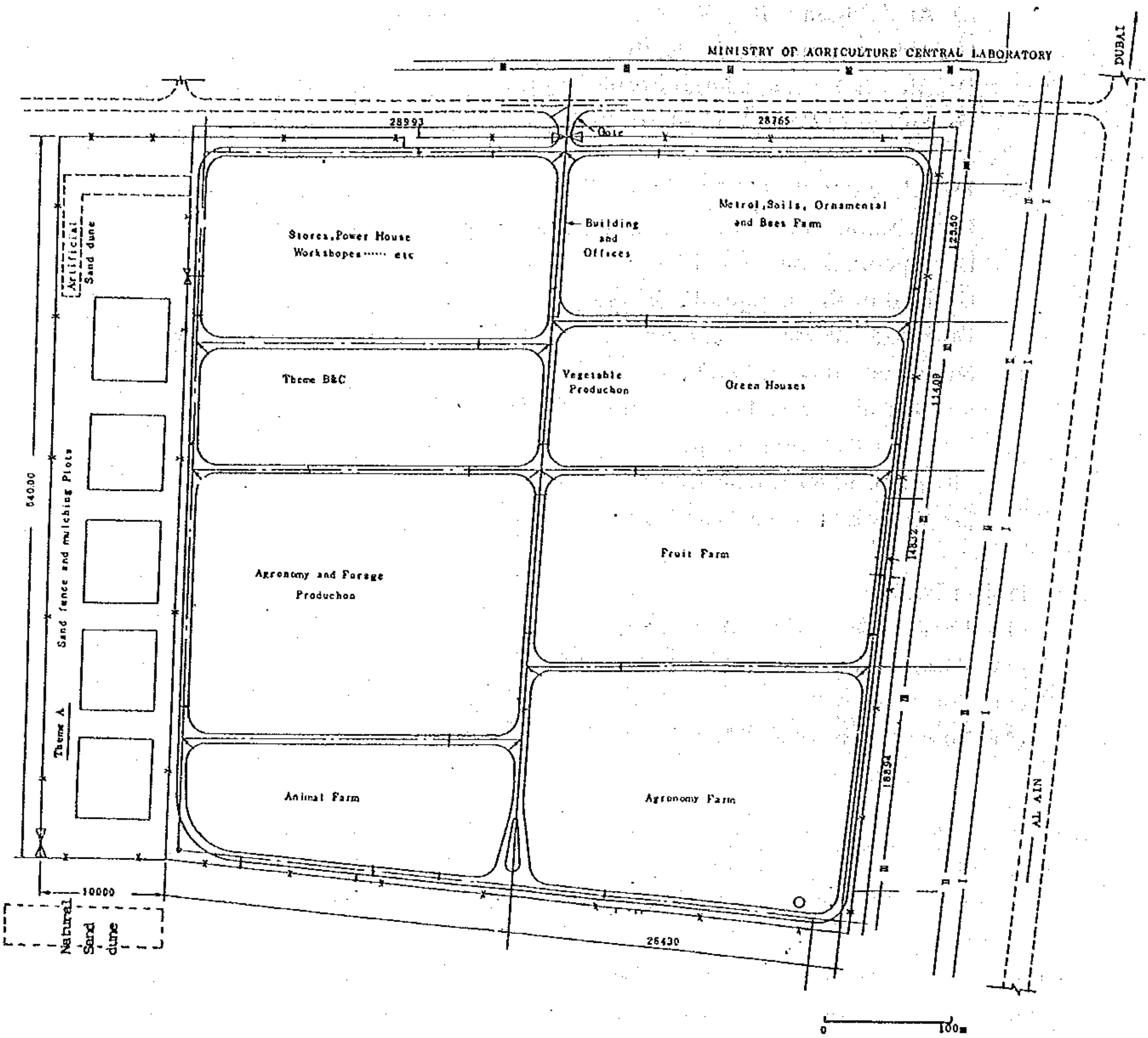


Fig. 1 University experimental farm

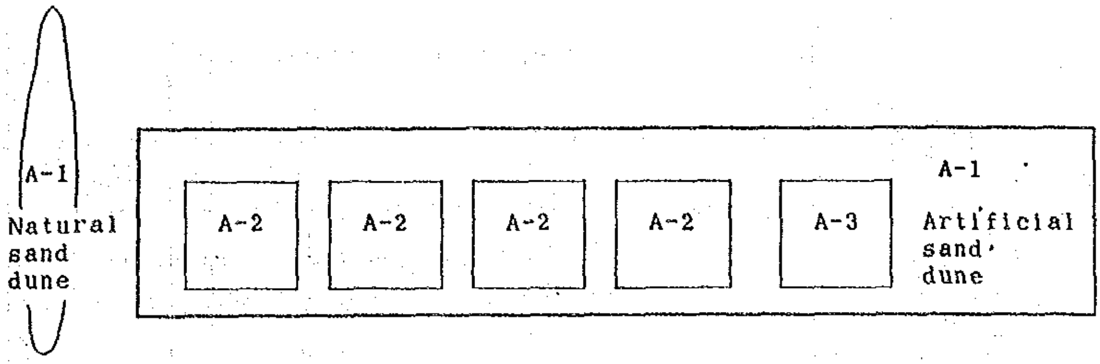


Fig. 2 Design of experimental plot on theme A

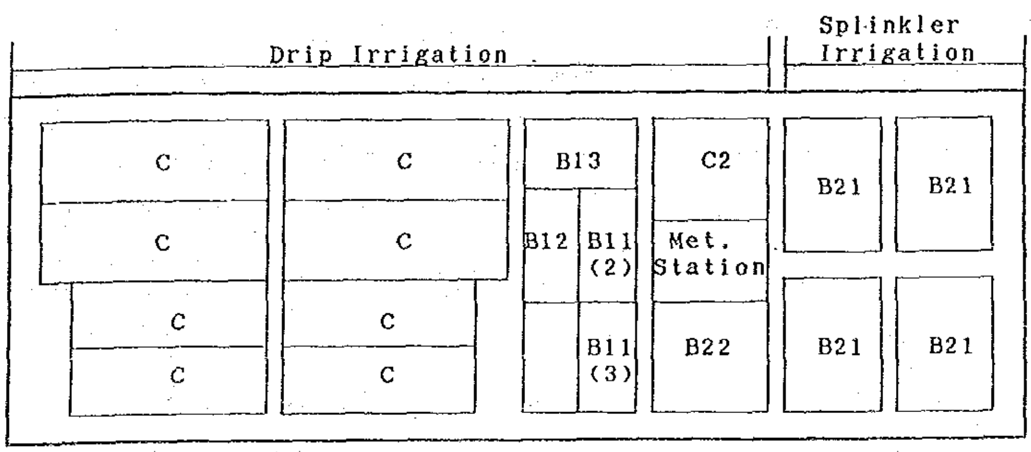


Fig. 3 Design of experimental plot on theme B and C

Table 1. Time schedule of the project

	Phase 1 (SEP '85 – AUG '86)	Phase 2 (SEP '86 – AUG '87)	Phase 3 (SEP '87 – AUG '88)	Phase 4 (SEP' 88 – MAR '89)
Theme A				
1. Experiment on Fixation of Sand Dune	Construction	Observation	Plantation & Mulching	
2. Effect on Different Density of Sand Fence		Construction of Fence	Observation	
3. Effect on Mulching and Water Holding Materials			Treatment, Plantation & Observation	
4. Effect on Different Materials of Sand Fence				
5. (1) Investigation of Afforestation Site		Investigations at the Various Sites		
(2) Monthly Tree Planting Trial		Monthly Plantation	Observation	
(3) Different Irrigation Levels Trial		Observation		
(4) Durability of Chemical Mulching		Observation		
(5) Preliminary Survey on Remote Sensing				
Theme B-1				
1. Effect of Thick Layer of Bark Compost				
(1) On the Growth of Alfalfa		Cultivation & Observation	Residual Effect	
(2) On the Growth of Wheat		Cultivation & Observation		
(3) On the Growth of Squash		Cultivation & Observation		
2. Effect of Compost Layer under Saline Irrigation				
(1) On Salt Accumulation		Treatment & Observation		
(2) On the Growth of Crop			Cultivation & Observation	
3. Comparison in Effect of Different Composts			Cultivation & Observation	
Theme B-2				
1. Growth Analysis of Wheat and Alfalfa		Cultivation & Observation		
2. Effect of Cultivation Methods on Microclimate		Cultivation & Observation		
Theme C				
1. Collection of Seeds	Collection			
2. Variety Test		Cultivation & Observation		
3. Screening Test			Treatment & Observation	
4. Studies on Crop Water Requirement			Treatment & Observation	

III. ABSTRACT OF THE EXPERIMENTAL RESULTS FOR THE YEAR 1985 – 1986

1–1. Daily meteorological record in the University Farm were summarized as monthly data.

1–2. The maximum advance velocity of natural sand dunes measured near the farm was approximately 2 m/month.

1–3. The greater part of blowing sand in sandy flat area of the desert was shown to shift at a height of less than 0.2 m from the ground surface.

1–4. The bamboo fence at the top of the sand dune was effective in preventing the movement of the sand dunes. The preventive ratio by bamboo fence for shifting sand was approximately 76% in comparison with the control plot.

1–5. In most of the afforestation areas observed in the UAE, some shrubs and grasses, such as Markha (*Leotadenia pyrotechica*) and Alta (*Colligonum commosum*), had been planted in the first stage to prevent shifting sand, and several kinds of trees, such as Samar (*Acasia tortilis*), Ghaff (*Prosopis spicigera*) and Arak (*Salvadora persica*) had been planted in the second stage. Also asphalt mulching before planting the trees had been conducted in several places of sand dune fixation project.

1–6. *Zygophyllum* sp. and *Hamada elegans* in Al Ain area tended to be dominant under soil conditions of high and low levels of both soil moisture and salinity, respectively.

2–1. Conventional sowing periods, planting periods and amounts of fertilizer used for crops and vegetables in the UAE were determined.

2–2. The soil in the Farm is sandy soil in taxture and contained approximately 20% of carbonate.

2–3. The salinity of well water in the Farm was classified C3 – S1 according to the criteria mentioned in the Handbook No. 60 (U.S.D.A.).

2–4. The arificial compost layer in a subsurface soil was effective to retain the irrigation water in compost layer and its upper soil layer.

3–1. Treatment of concentrated H_2SO_4 or hot water (80°C, 10 min.) was effective for breaking the dormancy of seeds of Samar and Ghaff.

3–2. The studies on the effects of irrigation level and planting dates on the growth of Samar and Ghaff will be continued.

IV. ABSTRACT OF THE EXPERIMENTAL RESULTS FOR THE YEAR 1986 – 1987

A-1. A Bamboo fence was established on the top of an artificial sand dune to introduce a new technique in sand dune fixation. The erosion of dune surface in windward slope and sand deposition in leeward slope were observed. The total amount of blowing sand was 3.11 Kg/100 cm^2, 1.78 Kg/100 cm^2 and 2.20 Kg/100 cm^2 at the top of the sand dune, at the windward foot and at the leeward foot, respectively.

A–2. Sand dune movement was investigated in a typical natural sand dune. The erosion in windward slope and the deposition in leeward slope were observed. The total amount of blowing sand was 64.97 Kg/100 cm^2 and 18.02 Kg/100 cm^2 at the top of the dune and its leeward foot, respectively.

A–3. Three different densities of date fronds mat fence were established in plots forming a checkerboard pattern, with distance of 10 m (D-10), 20 m (D-20) and 30 m (D-30). In addition, one plot was established as control. The date fronds mat fence was effective in prevention of shifting sand. The amount of shifting sand was 72.7%, 91.3% and 99.1% less than the control plot in D-30, D-20 and D-10 plot, respectively, during April to August 1987. The growth of Ghaff (*Prosopis spicigera*) was faster in fenced plots than in control plot. The relative height measured at 4 months after transplanting was 139 (D-10). 126 (D-20), 121 (D-30) and 100 (control), respectively.

A–4. Tree growth of Samar (*Acacia tortilis*), Ghaff (*Prosopis spicigera*) and Arak (*Salvadora persica*) was observed in an afforestation area of Al Ain Forestry Department at Al Wagon. The seasonal changes of growth process of each species and the changes in soil properties of EC and pH in the area were studied.

A–5. Some samplings of Samar and Ghaff were planted monthly to determine the most suitable time for transplanting under the conditions of the University Experimental Farm.

A–6. A preliminary experiment was conducted to study the performance of different kinds of mulching materials. The synthetic resin emulsion (Kuri-coat 720) was the most effective against wind erosion among the tested materials.

B–1. Thick layer application of bark compost in subsurface soil (T-treatment) increased the green matter yield of alfalfa compared to the two other treatments (whole layer application and control) under high and low irrigation levels.

B–2. Thick layer application of bark compost in subsurface soil (T-treatment) increased the grain yield of wheat under high irrigation conditions.

B–3. Thick layer application of bark compost in 10 cm and 20 m from the soil surface increased the fresh weight of squash tops compared to the control, although the fruit yield was not increased by the treatments.

B–4. Yields under local growing conditions were 1680 g/m^2 for alfalfa over a period of six months, and 277 g/m^2 of grains for wheat. In analyzing the growth parameters, alfalfa had a peak of Leaf area index (LAI) and CGH in early May of 5.5 and 14.4 g/m^2/day, respectively. However, wheat had a rapid decrease in LAI and a later peak in CGR in early Feb. of 35.5 g/m^2/day.

B–5. Both high irrigation frequency and dence plant cover reduced soil temperature at shallow depths, while irrigation amount had no effects when observed in September and December 1986.

B–6. Productive performances were studied in a 4-year old sward of alfalfa located near Al Ain-city, UAE, in December. The shoot yield and LAI were 147.6 g/m^2 and 1.18, respectively.

B–7. Productive performance were studied in a 6-year old sward of alfalfa located in Al Ain-city, UAE, in September. The shoot yield and LAI were 99.5 g/m^2 and 0.91, respectively.

V. THE EXPERIMENTAL RESULTS FOR THE YEAR 1986 – 1987

1. Theme A : Studies on Sand Dune Fixation by Methods of Revegetation Work with Civil Engineering

(1) Experiment of Sand Dune Fixation

ABSTRACT

Bamboo fence was established on the top of an artificial sand dune as introduction of a technique of sand dune fixation.

The erosion of dune surface was recognized remarkably in windward slope, and sand deposition was noticed in leeward slope.

The total amount of blowing sand was 3.11 kg/100 cm^2., 1.78 kg/100 cm^2 and 2.20 kg/cm^2 at the top of sand dune, at the windward foot and at the leeward food, respectively, which was measured at three different heights duing from January to July in 1987. The amount of captured sand was the largest in March 1987 during the measurement period.

INTRODUCTION

Sand movement is a common natural phenomenon in desert regions. The sand in those regions is blown away by wind, and shifting sand invades or buries residence areas, roads and farms. Therefore, it is very important to prevent the shifting sand. The purpose of this experiment is to establish the technique of sand dune fixation.

MATERIALS AND METHODS

An artificial sand dune was constructed in order to establish the technique of sand dune fixation in the north corner of the experimental area (Fig. 1). The sand dune was 180 m in length and 4 m in height as shown in Figs. 2 and 3. The construction of artificial sand dune was completed in September 1986, and a bamboo sand fence was established on the top of sand dune in October 1986 (Fig. 4).

To evaluate the effects of bamboo fence, the following measurements were conducted; 1) short-term topographic change measured by exposed length of fixed pile, 2) long-term topographic change measured by auto-level and pocket-compass, and 3) amount of blowing sand at different height measured by capture equipments with revolving system. The sand capture equipments were set up at different heights of 0.2, 0.5 and 1.5 m from the ground surface, respectively (Fig. 5), which were located on both south and north foot of sand dune and the top of sand dune on Line No. 2 (Fig. 2). The amount of blowing sand and the length of exposed piles were measured everly 10 days. The long-term topographic change was measured in September 1986, April and September 1987.

RESULTS AND DISCUSSION

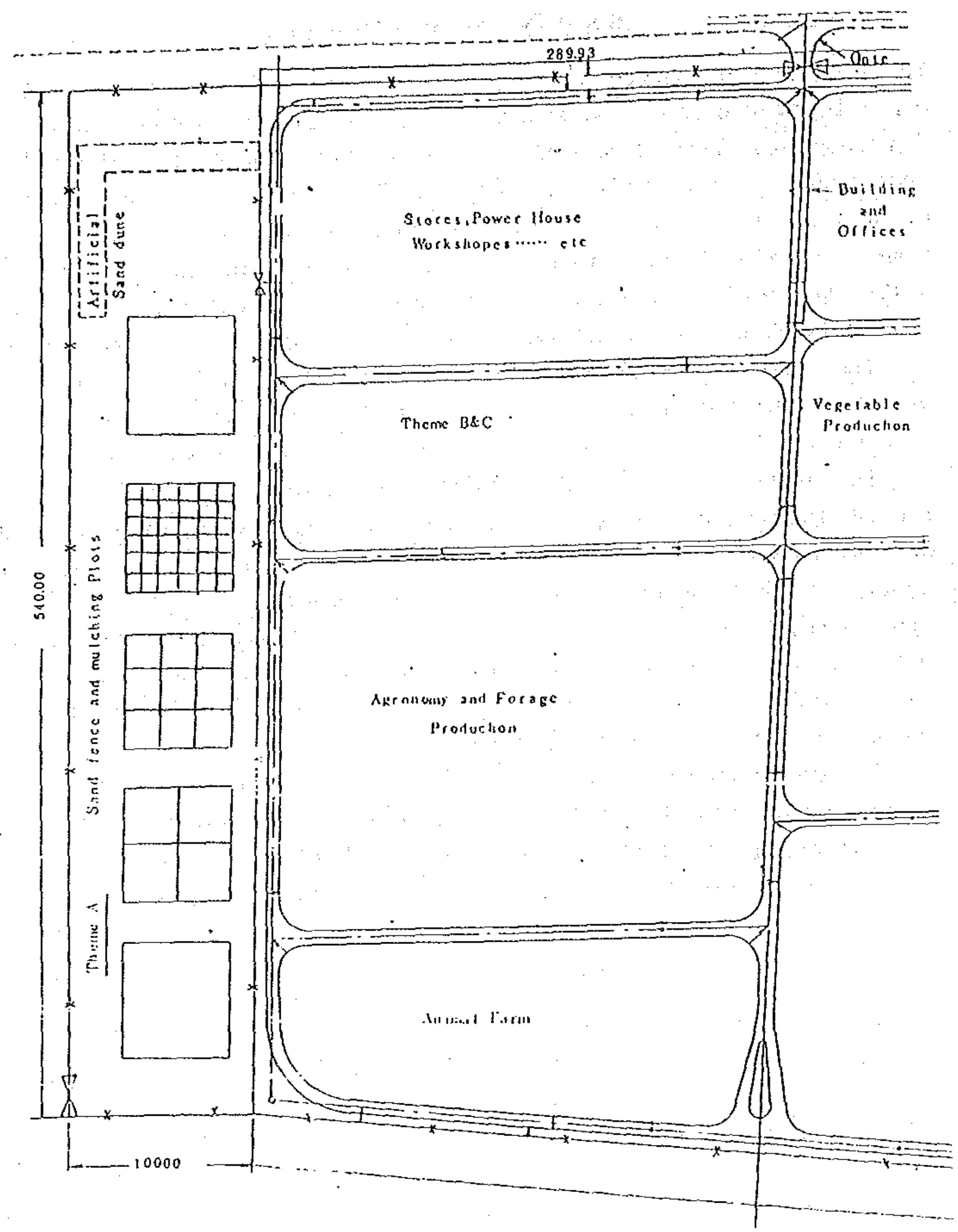
The change of exposed length of each pile are shown in Tables 1 and 2, and the additional change length of fixed piles are arranged by absolute value as shown in Table 3. It shows that topographic change of the sand dune top was more remarkable than the slope of both sides of dune especially in Line No. 5 to No. 7. The mean values of three lines from No. 1 to No. 3 were 36.7 cm, 51.2 cm and 21.6 cm at the top of sand dune, at the windward foot (south side) and at the leeward foot (north side), respectively. In contrast, the mean values of three lines from No. 5 to No. 7 were 90.6 cm, 37.4 cm and 26.0 cm at the top of sand dune, at the windward foot (west side) and at the leeward foot (east side), respectively.

The change of cross section of the sand dune is shown in Fig. 8. Erosion of dune surface was recognized remarkably in both south and west slopes which were windward sides, and sand deposition was noticed in both north and east slopes which were leeward.

The amount of blowing sand at different heights from ground surface is shown in Table 4. The amount of blowing sand increasing accordance with decrease in the height from ground surface at three measurement points. The major part of blowing sand was captured at height less than 0.2 m. The total amount measured in weven months during from January to July in 1987 were 3.11 Kg/100 cm^2, 1.78 kg/100 cm^2 and 2.20 kg/100 cm^2 at the top of sand dune, at the windward foot and at the leeward foot, respectively. The amount of captured sand was the largest in March 1987 during the measurement period, when it was experienced very strong wind.

The bamboo fence on the top of sand dune will be removed in next stage of this experiment (October 1987) in order to clarify its effect on wind erosion control.

The time schedule of the experiment is shown in Table 5.



Natural Sand Dune

University Experimental Farm

Fig. 1 Layout of experimental plots of Theme A

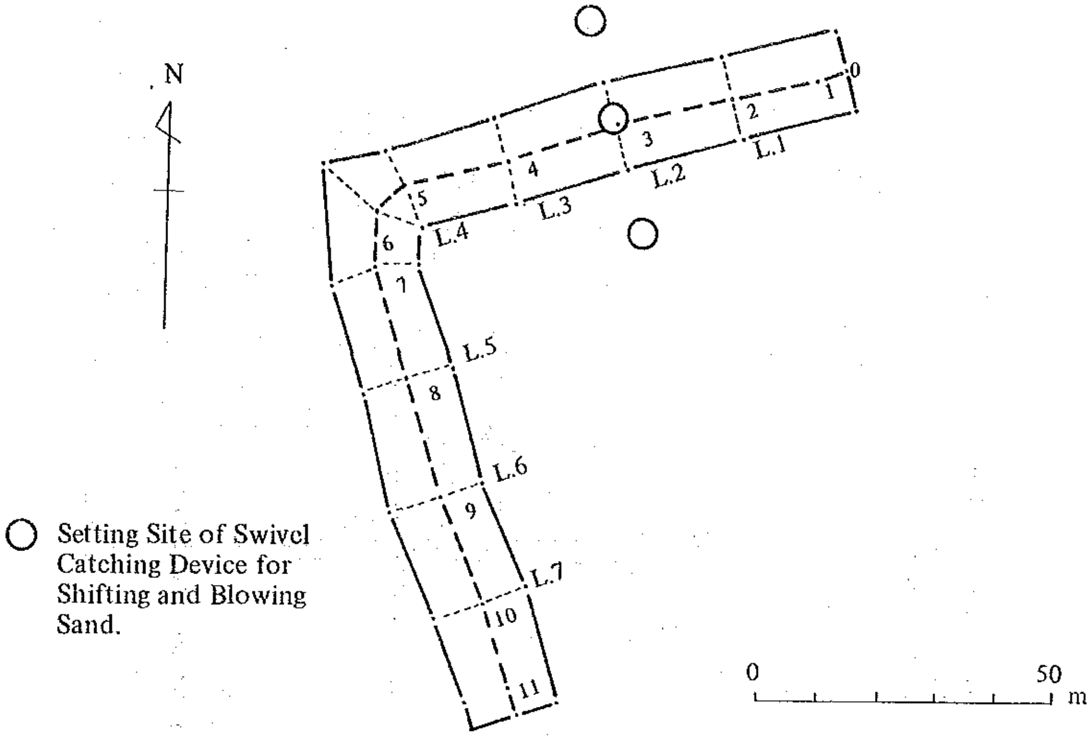


Fig. 2 Plane figure of the artificial sand dune

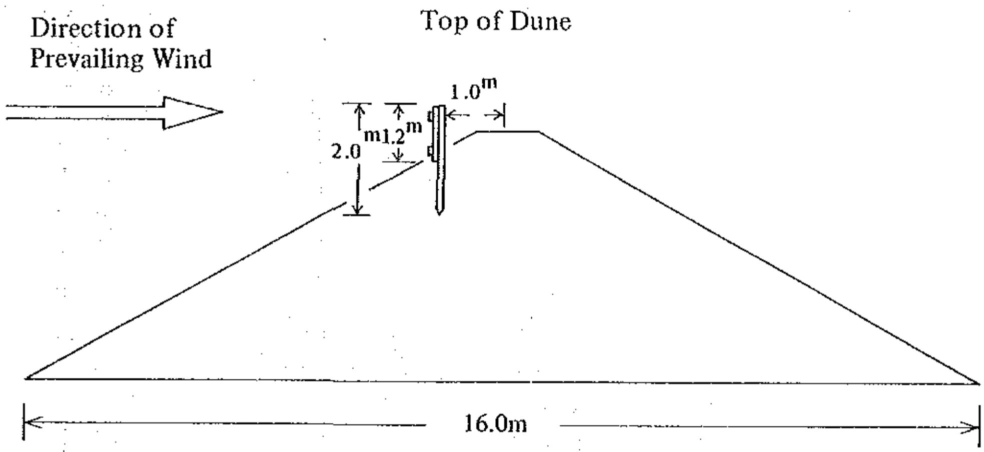


Fig. 3 A cross section figure of the artificial sand dune

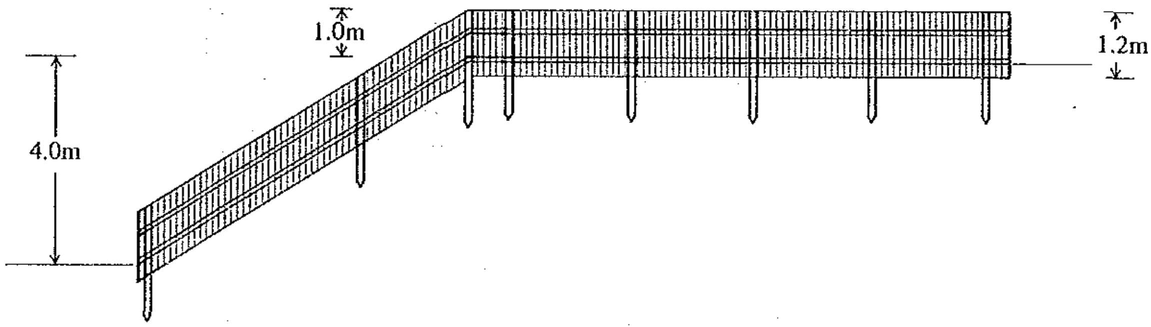


Fig. 4. Structure figure of the bamboo sand fence on top of sand dune

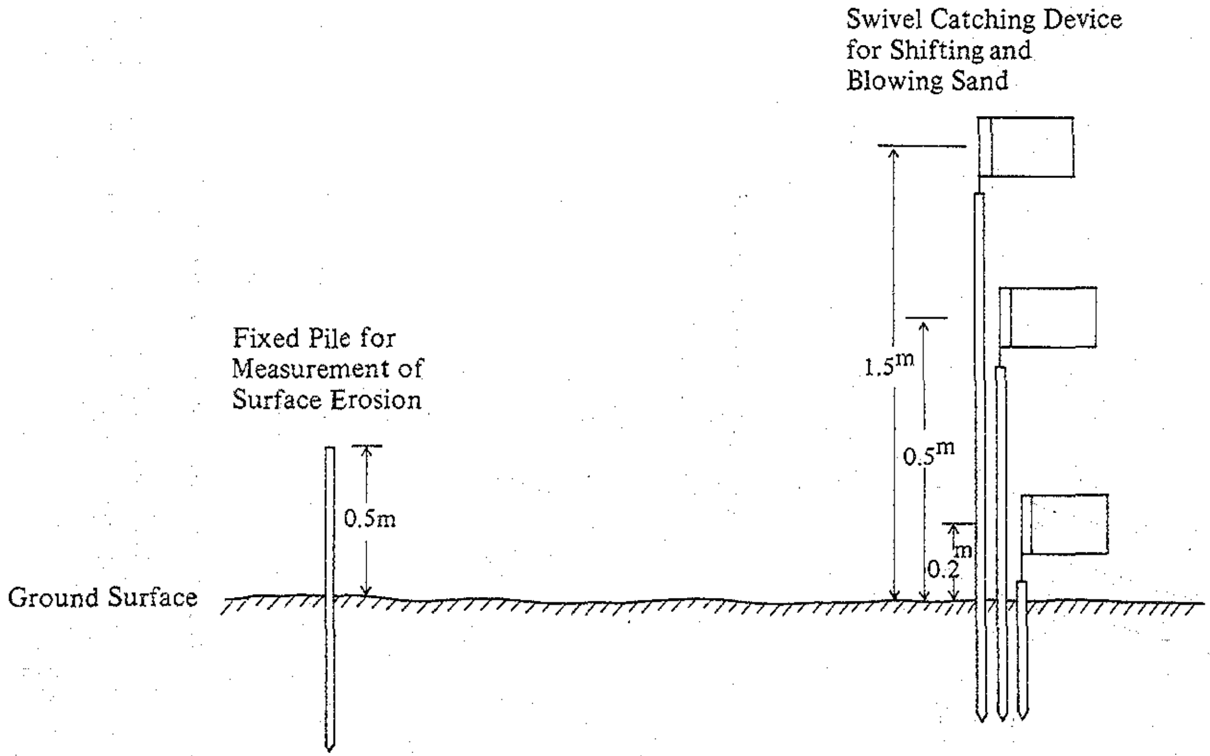


Fig. 5 **Setting condution of the fixed pile for erosion measurement and the capture equipment with revolving system of blowing sand**

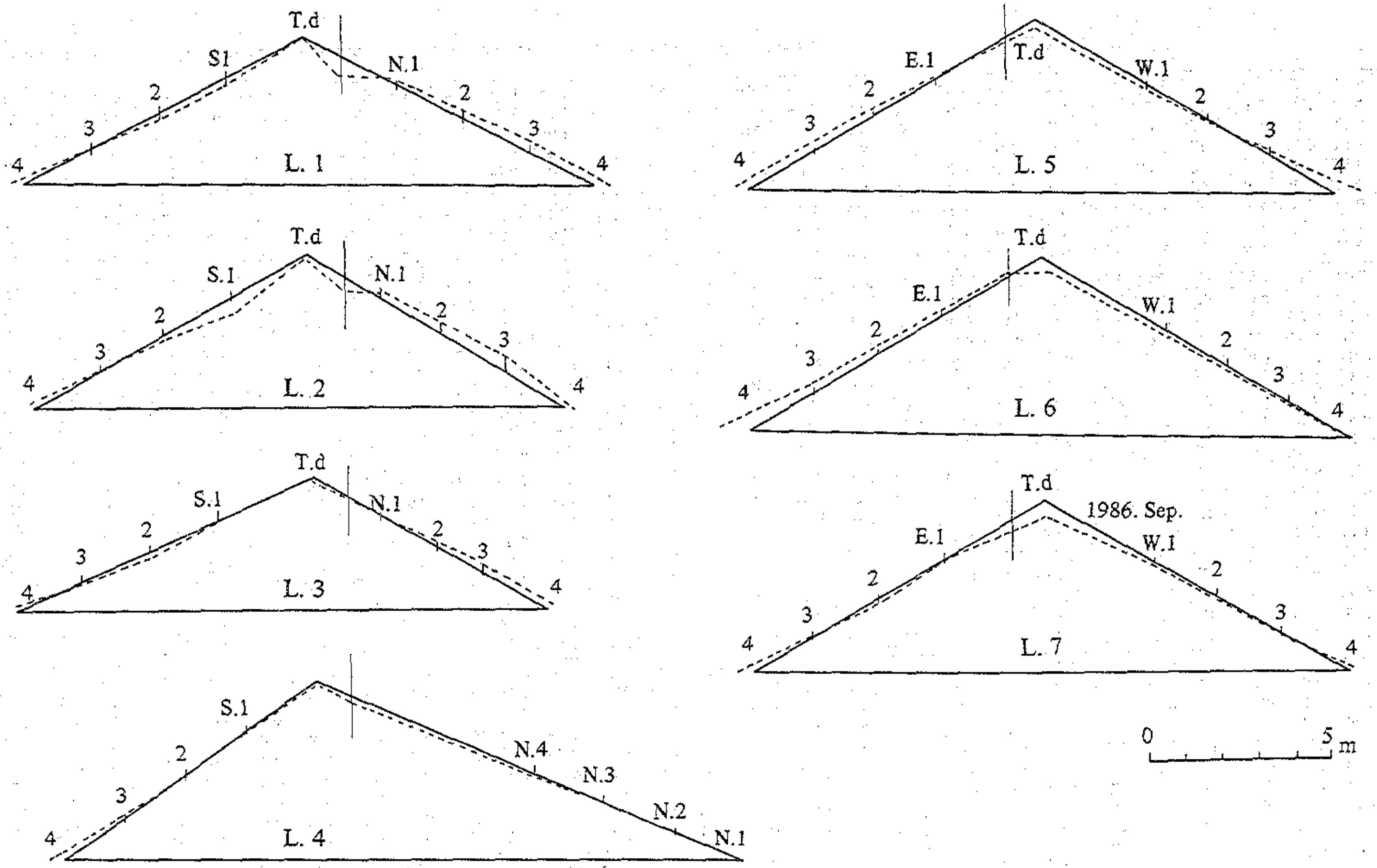


Fig. 6 Change of the cross section of artificial sand dune

Table 1. The change of exposed pile length on artificial sand dure (1987, Jan. ~ Aug.)

No. 1

Line No.	Pile No.	H.G. (cm)	1.31	2.14	2.22	2.28	3.14	3.21	3.28	4.5	4.10	4.20	4.30	5.10	5.20	5.31	6.10	6.20	6.30	7.10	7.20	7.31	8.10	8.20	8.31	N.M.	Σ|A| (cm)	Σ|E| (cm)	(cm)	(cm)
			Change in high of measuring piles (cm)																											
	N4	39	−0.5	+0.5	+1.0	−0.2	−2.7	+12.1	+7.9	0.0	0.0	0.0	+0.5	−3.0	+0.9	+1.2	+0.4	+0.5	−0.1	+0.4	−0.1	+1.8	+3.5	−1.5	−3.0	23	30.7	11.1	41.8	+19.6
	3	131	+0.5	+6.5	+3.0	0.0	+5.0	+16.5	+2.0	0.0	+2.3	+1.2	−0.8	−3.6	−0.6	+0.3	−2.8	−1.8	−1.2	−0.8	−0.4	+1.2	−3.6	+4.4	+4.5	23	47.4	15.6	63.0	+31.8
	2	236	−1.1	+4.6	0.0	−0.5	0.0	−2.0	−1.0	−0.5	0.0	+0.4	+1.5	+4.1	+4.0	+3.0	+0.5	0.0	−0.5	+0.5	−0.5	+3.6	−0.7	+2.8	+0.5	23	25.5	6.8	32.3	+18.7
	1	341	−1.3	−5.7	0.0	−2.0	+1.0	−6.0	−1.0	−1.0	0.0	+0.1	+1.9	−0.3	−0.2	−0.1	+0.4	+2.7	+4.0	+4.5	−0.6	+4.4	−1.0	+5.6	+2.6	23	27.2	19.2	46.4	+8.0
1	T	396	−0.5	−2.1	−0.4	0.0	0.0	−1.3	−1.2	+0.5	0.0	+0.1	+13.9	−3.9	−0.1	−0.5	+0.5	+0.5	0.0	−0.7	+0.1	−1.4	−2.5	−3.0	+0.1	23	15.7	17.6	33.	−1.9
	S1	354	−1.0	−1.5	+0.5	−0.5	−0.5	−4.5	−0.7	−1.8	−0.5	−0.3	+0.1	−0.3	−0.4	−0.1	+0.1	+0.4	−0.3	0.0	0.0	−1.9	−4.3	−3.5	+1.5	23	2.6	22.1	24.7	−19.5
	2	257	−1.0	−0.9	+0.4	−0.5	0.0	−0.5	0.0	−0.5	0.0	−0.5	−0.5	−1.0	+0.2	0.0	−0.2	+0.5	+0.2	−0.2	0.0	−0.4	−5.1	+0.3	−0.8	23	1.6	12.1	13.7	−10.5
	3	154	+0.3	−1.7	+0.1	−0.2	−0.5	0.0	+0.5	−0.5	0.0	−0.4	−0.1	−0.1	+0.5	−0.4	+0.2	+0.2	−0.3	−0.1	0.0	−0.4	−0.7	+2.2	+0.4	23	4.4	5.4	9.8	−1.0
	4	76	+0.4	+0.3	+1.6	−0.7	+1.0	+1.0	+1.0	+2.0	+1.3	+0.8	+0.8	+3.1	+1.1	+2.4	+1.0	+1.5	0.0	+0.5	0.0	+1.0	−1.7	+1.8	−0.3	23	22.6	2.7	25.3	+19.9
	N4	18	−1.1	+0.8	+0.3	0.0	+2.0	+7.0	+9.0	+0.5	+1.5	+1.5	+2.5	−0.5	+.23	+2.2	+1.8	+1.8	+0.6	+1.8	+0.2	+1.8	+2.0	+3.2	+4.7	23	47.5	1.6	49.1	+45.9
	3	100	+0.2	+6.3	+2.0	+1.0	+5.5	+24.0	+9.0	+3.0	+3.0	+1.4	−1.7	−5.9	+1.7	0.0	−2.3	−1.2	−1.0	−1.0	−0.3	0.0	−6.2	△	△	21	57.1	19.6	76.7	+37.5
	2	206	−1.0	+7.2	+3.3	+1.0	+3.0	+6.0	−1.5	−1.0	+0.5	+0.2	+0.7	+1.3	−0.1	+0.4	+1.0	0.0	−0.2	+0.7	−1.0	+4.5	+1.4	+2.8	+1.1	23	35.1	4.8	39.9	+30.3
	1	312	−2.0	−1.0	−3.5	−1.5	−2.0	−5.0	−1.0	−0.5	0.0	0.0	+3.0	+4.1	−0.0	+2.0	+1.8	+0.5	+7.5	+1.0	−1.0	+15.0	+0.2	+7.6	+0.1	23	42.8	18.4	61.2	+24.4
2	T	396	0.0	+5.5	−2.5	+2.0	−1.0	−8.0	−5.0	−0.5	0.0	+0.9	+2.6	−0.2	−2.0	−1.8	+0.5	+1.0	−1.0	+0.7	−0.5	−2.3	−0.4	−2.2	0.0	23	13.2	27.4	40.6	−14.2
	S1	321	−1.0	−5.5	−2.5	0.0	−1.0	−11.0	−1.0	+0.5	−1.5	−0.3	−0.2	−2.0	−1.7	+0.2	0.0	+1.4	−1.5	−0.9	+0.1	−3.1	−4.0	−14.5	−1.0	23	2.2	52.7	54.9	−50.5
	2	225	−0.5	−2.2	−1.8	−0.5	−1.0	−8.0	0.0	0.0	−0.3	−0.7	+0.4	−0.9	0.0	−0.1	−0.2	+0.3	−0.9	+0.4	−0.2	−1.7	−2.6	△	△	21	1.1	21.6	22.7	−20.5
	3	128	0.0	−0.4	+0.1	−0.2	0.0	−0.5	0.0	0.0	−0.5	−0.1	+0.1	−1.2	+0.1	+0.1	0.0	+0.1	−0.1	−0.1	0.0	−0.7	+0.7	△	△	21	1.2	3.8	5.0	−2.6
	4	53	+0.5	+0.3	+0.2	0.0	+0.5	+0.5	+0.5	+1.5	+1.5	+1.2	+1.8	+3.0	+1.1	+0.4	+0.5	0.0	−0.4	−0.1	+0.1	+1.9	+1.7	△	△	21	17.2	0.5	17.7	+16.7
	N4	52	0.0	+1.7	+2.1	−0.5	+2.2	+6.0	+3.0	+5.5	+5.2	+2.7	+1.6	+10.7	−0.2	+2.5	+2.5	+0.8	+0.8	+2.1	−0.2	+4.8	+4.4	+1.8	+2.4	23	61.8	0.9	62.7	+60.9
	3	152	0.0	+2.2	+0.7	−0.4	+0.5	+4.7	+0.3	0.0	+0.2	−0.2	−0.4	+0.2	+0.2	−0.5	0.0	−0.6	+0.1	+0.4	−0.1	+1.7	+3.1	+1.7	+0.6	23	16.6	2.2	18.8	+14.4
	2	257	−0.7	+1.9	+2.3	−1.0	+1.0	+3.5	+2.0	−0.5	+1.5	0.0	−3.0	0.0	0.0	−0.2	−1.8	−1.6	+0.6	−0.5	−0.5	+4.0	+1.7	+2.9	−0.6	23	21.4	10.4	31.8	+11.0
	1	361	0.0	−1.5	−1.0	−0.5	+1.0	−1.0	0.0	0.0	−1.2	0.0	+4.2	+1.3	−0.3	−2.0	+0.6	+1.0	−1.6	+1.0	−1.0	−1.2	+0.1	+2.6	+1.3	23	13.1	11.3	24.4	+1.8
3	T	419	−0.5	−0.5	−1.0	+1.5	+0.5	−2.5	−1.5	0.0	0.0	+1.5	+9.0	−3.5	+0.4	−2.4	+1.4	+0.6	−1.1	+0.1	−0.6	+0.1	−3.7	−3.6	+0.3	23	15.4	20.9	36.3	−5.5
	S1	341	−2.0	0.0	+0.5	+0.5	0.0	−3.5	+0.5	−1.0	0.0	−0.2	+0.1	0.0	−0.5	−0.1	0.0	+0.7	−0.5	−0.3	0.0	+2.8	−5.5	−0.5	−1.3	23	5.1	15.4	20.5	−10.3
	2	243	−1.1	−1.9	0.0	+0.2	−0.3	−2.0	0.0	−0.5	0.0	−0.2	+0.4	−0.5	+0.2	−0.4	+0.5	+0.3	−0.4	−0.3	+0.1	−0.5	−0.7	−1.5	−0.5	23	1.7	10.8	12.5	−9.1
	3	240	−0.3	−0.7	−0.3	+0.2	−0.5	0.0	−0.5	−0.5	−0.2	−0.3	−0.2	−0.3	−0.2	0.0	+0.2	0.0	−0.3	−0.2	0.0	−0.5	−0.5	−0.2	−1.0	23	0.4	6.7	7.1	−6.3
	4	42	−1.0	+1.0	+0.3	+0.5	+1.2	−1.0	+1.5	0.0	+0.2	+0.4	+0.9	+2.5	+1.1	+0.4	+0.2	−0.2	+0.5	−1.5	+0.5	+1.5	+2.9	+2.6	0.0	23	18.2	3.7	21.9	+14.5
	N4	66	−1.0	−0.7	+0.2	−0.4	−0.1	−0.3	−0.5	−0.7	+0.1	0.0	−0.7	+0.6	−0.5	+0.3	+1.1	−1.4	+0.1	0.0	+0.1	+3.0	−0.5	+0.7	+0.6	23	6.8	6.8	13.6	0.0
	3	134	−1.0	−1.2	+0.2	−0.7	+0.2	−0.5	+0.1	−0.1	0.0	−0.4	−0.3	−0.1	−0.2	0.0	+0.5	−0.5	0.0	0.0	0.0	+0.3	−0.7	+0.4	0.0	23	1.7	5.7	7.4	−4.0
	2	197	0.0	−1.5	30.5	−0.6	+0.6	−1.4	+0.4	−1.0	+0.5	−0.2	−0.6	−0.2	+0.1	−0.1	0.0	−0.6	−0.2	0.0	+2.3	−1.8	−2.0	+0.3	+0.6	23	5.3	10.2	15.5	−4.9
	1	265	+1.0	−1.5	+0.5	−0.9	+0.9	−0.5	+0.5	−1.0	+0.1	+0.3	0.0	−4.6	+0.5	−0.1	0.0	0.0	−0.2	0.0	0.0	−0.2	−1.8	+0.8	+0.1	23	9.2	10.8	20.0	−1.6
4	T	411	−1.0	−2.0	0.0	−0.5	+0.5	−0.2	−0.8	+1.0	0.0	+0.5	+0.5	−3.5	+0.5	−0.1	+0.1	+0.3	−0.2	−0.1	0.0	−1.0	−4.0	+1.0	−2.3	23	8.9	15.7	24.6	−6.8
	S1	328	−2.1	−1.9	+1.0	0.0	0.0	−4.0	+1.0	−0.5	−0.5	+0.4	−0.2	−1.9	−0.1	−0.3	−0.2	+0.5	−0.5	−0.2	0.0	−0.2	−2.3	△	△	21	2.9	14.9	17.8	−12.0
	2	221	−0.3	−0.8	+0.6	+0.1	−1.1	−1.5	0.0	0.0	−0.3	−1.1	−0.1	0.0	−0.5	+0.2	+0.1	+0.3	0.0	−0.1	0.0	−0.5	−2.1	+0.9	−0.2	23	2.2	8.6	10.8	−6.4
	3	118	0.0	−0.2	+0.2	0.0	0.0	0.0	0.0	0.0	−0.5	0.0	+0.2	+0.5	−0.2	+0.5	+1.0	+1.1	0.0	+1.4	+0.3	−0.2	−2.4	+2.0	−0.7	23	7.2	4.2	11.4	+3.0
	4	28	+0.8	+0.6	+0.6	+0.1	+0.9	+1.0	+1.0	+0.5	+0.1	+1.1	+1.1	+2.2	+2.4	+1.6	+1.6	+1.6	+1.5	+1.5	+0.5	+0.5	+2.0	+2.9	−0.5	23	26.1	0.5	26.6	+25.6

H.G. : Height of Ground-surface N.M. : Number of Measuring A : Accumulation E : Erosion △ : Unmeasured

Table 2. The change of exposed pile length on artificial sand dure (1987. Jan. ~ Aug.)

No. 2

Line No.	Pile No.	H.G. (cm)	Change in high of measuring piles (cm) 1.31	2.14	2.22	2.28	3.14	3.21	3.28	4.5	4.10	4.20	4.30	5.10	5.20	5.31	6.10	6.20	6.30	7.10	7.20	7.31	8.10	8.20	8.31	N.M.	Σ|A| (cm)	Σ|E| (cm)	(cm)	(cm)
	W4	7	+0.1	+0.8	+4.8	+0.2	−0.2	−1.7	−0.3	).0	+0.7	+0.2	+0.1	+2.1	0.0	+1.3	+0.5	−0.1	+0.5	0.0	+0.1	+2.7	+3.1	+4.5	+2.0	23	23.7	2.3	26.0	+21.4
	3	99	−0.1	−0.2	+4.2	−0.1	−1.3	−2.5	0.0	−0.5	−0.1	−0.8	0.0	+0.4	−0.1	−0.5	−0.1	+0.5	0.0	+0.2	+0.6	−0.3	+5.2	+4.3	+0.8	23	16.2	6.6	22.8	+9.6
	2	199	−0.7	−1.6	+1.9	−0.2	−1.4	−2.5	−0.5	0.0	−0.2	+0.1	+0.1	+3.8	−2.3	−1.0	−0.5	+0.5	0.0	−0.3	+0.3	+1.7	+8.9	+0.6	−0.3	23	17.9	11.5	29.4	+6.4
	1	303	−1.5	−2.5	+0.5	0.0	+2.0	−4.0	−1.5	+0.5	+2.0	−2.0	+1.0	+5.2	−1.8	−0.9	−0.3	+0.3	−1.3	+0.3	+0.6	+1.2	+5.2	+1.7	+0.8	23	21.3	15.8	37.1	+5.5
5	T	417	0.0	+0.8	+1.7	−0.5	+5.0	+2.5	−1.5	+1.0	−0.2	+3.8	+2.2	−17.3	+3.5	+4.9	−3.4	+3.3	−3.1	+0.7	−1.7	−13.5	−15.5	−0.5	0.0	23	29.4	57.2	86.6	−27.8
	E1	309	−1.3	−0.7	+1.5	−0.5	−1.0	0.0	+1.0	−1.0	−1.0	−1.2	0.0	−6.8	+0.3	+0.2	−0.8	+0.8	−1.1	−0.7	+0.1	−0.6	−8.5	+0.9	0.0	23	4.8	25.2	30.0	−20.4
	2	210	−1.5	+1.5	+7.2	+0.3	−2.5	−3.0	−4.0	−1.5	−2.5	−0.4	+0.6	−2.9	+0.9	+3.3	−1.3	+1.0	+0.1	+0.2	0.0	+4.5	−11.4	−0.3	−2.3	23	19.6	33.6	53.2	−14.0
	3	106	−1.5	+3.5	+6.8	+1.2	+0.5	−3.5	−2.0	−1.5	+1.0	+2.3	−1.8	−0.2	−0.1	+1.8	−1.3	−0.2	+0.2	−0.7	+0.5	+3.2	−3.7	−0.5	0.0	23	21.0	17.0	38.0	+4.0
	4	27	−1.0	+7.3	+8.7	+0.5	+1.2	−0.7	0.0	0.0	+1.0	+0.2	−1.1	−0.1	−0.5	0.0	−0.7	−0.3	0.0	−0.5	−0.9	+0.5	−0.2	+2.8	+1.3	23	23.5	6.0	29.5	+17.5
	W4	0	+0.2	+1.1	+4.2	+1.0	+0.5	+3.8	+2.7	+4.5	+0.7	+1.0	−0.3	+3.6	+2.0	+1.0	+1.0	−0.1	+0.6	+0.1	+0.4	+6.8	+4.2	+22.	−1.1	23	41.6	1.5	43.1	+40.1
	3	91	−0.3	−2.6	+2.9	−1.0	−1.0	−1.0	0.0	0.0	0.0	−0.1	−0.1	+3.2	+1.8	+0.7	+1.5	0.0	+1.0	+0.4	−0.2	+8.8	+1.2	−0.1	+2.2	23	23.7	6.4	30.1	+17.3
	2	190	−0.5	−2.0	+2.9	−0.2	−1.3	−0.6	−2.9	0.0	−0.3	−1.3	+0.1	+8.5	−2.0	−0.7	−0.6	−1.3	−0.7	−1.2	+0.5	+7.2	+8.8	−0.8	+1.0	23	29.0	16.4	45.4	+12.6
	1	295	−3.0	−1.2	+1.7	0.0	−0.5	−3.0	−1.0	0.0	−1.5	−0.8	+0.3	+8.5	−2.8	−1.7	−1.2	−1.0	−0.8	−1.0	0.0	+8.0	+10.5	−1.1	−4.9	23	29.0	25.5	54.5	+3.5
6	T	424	0.0	+0.6	−0.6	0.0	+0.5	+5.5	−3.7	+0.7	0.0	+2.4	+2.8	−20.2	+4.6	+5.4	−2.2	+8.8	−4.6	+8.0	−3.0	−23.0	−18.2	−3.0	+6.9	23	46.2	78.5	124.7	−32.3
	E1	313	−2.0	−1.0	+25.	+0.5	+2.0	+2.0	−3.5	−1.0	−3.0	−0.5	+0.5	−3.0	−0.4	+0.7	−1.8	−0.4	−0.6	−0.1	−0.3	−8.6	−9.0	+2.0	0.0	23	10.2	35.2	45.4	−25.0
	2	212	−0.5	+4.5	+7.4	+0.6	−2.0	−0.5	+0.5	−0.5	0.0	+0.5	−0.3	−6.6	+2.2	+3.2	−0.8	−0.2	+1.0	0.0	0.0	−0.5	−9.5	−5.8	+2.9	23	22.8	27.5	50.0	−4.4
	3	107	+0.1	+4.1	+6.0	+1.3	+1.0	+2.5	+1.5	−4.5	+2.0	+2.2	0.0	−0.1	+2.6	+1.7	−1.0	−0.2	+1.2	−0.5	+0.2	−0.2	−4.5	+0.5	+1.0	23	27.9	11.0	38.9	+16.9
	4	16	+1.2	+4.3	+7.0	+0.5	+2.0	+5.0	+2.5	+1.5	0.0	−0.3	+0.5	−0.3	+0.6	−0.3	−0.5	+0.2	+0.9	−0.8	+0.4	+0.2	+0.8	+1.2	+2.2	23	31.0	2.2	33.2	+28.8
	W4	35	+0.2	0.0	−1.7	−0.5	−1.0	−4.0	0.0	−0.5	+0.3	−0.3	+0.2	+14.4	+1.7	+0.2	+4.5	+2.1	+1.2	+0.9	−0.2	−1.1	+4.6	+0.3	−3.3	23	30.6	12.6	43.2	+18.0
	3	105	−0.5	−1.1	−1.4	0.0	−1.5	−0.5	0.0	−0.5	+0.5	+0.5	+0.2	+2.3	−0.3	−1.7	+0.5	+1.0	−0.8	−1.1	+0.4	−0.8	+1.8	+1.0	+1.5	23	9.7	10.2	19.9	−0.5
	2	209	−0.5	−0.5	−1.0	−0.2	−0.8	−1.5	−0.5	−1.0	+0.3	−0.1	+0.1	+5.2	−2.5	−1.9	−0.9	−0.4	+0.9	−1.0	+0.1	+1.0	+6.7	−7.0	−1.2	23	14.3	21.0	35.3	−6.7
	1	313	−0.8	−1.7	−0.5	−0.2	+0.2	−2.0	−2.0	−0.5	−0.5	−0.5	0.0	+5.1	−3.6	−1.0	−0.5	−1.0	−1.5	−0.4	+0.1	+1.5	0.0	−0.5	+7.5	23	14.4	17.2	31.6	−2.8
7	T	384	−1.0	−1.2	+0.2	−0.5	−3.0	+5.5	−1.5	+0.5	−2.0	+1.4	+1.3	−12.1	+1.0	−0.1	−0.7	+2.7	−1.5	+1.4	−0.3	−7.3	−11.3	−2.5	−1.5	23	14.0	46.5	60.5	−32.5
	E1	365	−0.2	−0.8	−0.0	−0.5	+0.5	−1.0	+0.5	−0.5	0.0	−0.8	+1.8	−6.0	+0.4	+0.6	−0.6	+0.1	−0.5	−0.2	+0.2	−4.4	+2.7	−10.6	−1.2	23	6.8	27.3	34.1	−20.5
	2	236	+0.2	−2.4	−1.4	−0.5	−2.9	0.0	+2.0	−3.0	+1.0	−2.7	−0.5	−2.8	+1.5	−2.2	+0.1	+1.3	+0.8	−1.0	+0.4	−3.7	−2.4	+1.2	−0.8	23	8.5	26.3	34.8	−17.8
	3	128	+1.2	−0.2	−0.6	−0.6	−0.3	−1.5	+1.5	−1.5	−3.5	−0.9	+0.1	−0.2	0.0	−0.3	+0.3	0.0	+0.1	−0.9	+0.9	−1.5	−0.9	+0.9	+0.6	23	5.6	12.9	18.5	−7.3
	4	33	−0.3	−0.7	+1.0	−0.5	0.0	+0.5	+3.0	−2.5	0.0	+0.2	+0.2	+0.6	−1.0	+0.3	+0.7	0.0	0.0	−0.5	0.0	−0.8	+0.2	+1.6	+0.7	23	9.0	6.3	15.3	+2.7

H.G. : Height of Ground-surface N.M. : Number of Measuring A : Accumulation E : Erosion

Table 1. The change of exposed pile length on artificial sand dure (1987, Jan. ~ Aug.)

No. 1

Line	Pile	H.G.	Change in high of measuring piles (cm)																							N.M.	$\Sigma\lvert A\rvert$	$\Sigma\lvert E\rvert$		
No.	No.	(cm)	1.31	2.14	2.22	2.28	3.14	3.21	3.28	4.5	4.10	4.20	4.30	5.10	5.20	5.31	6.10	6.20	6.30	7.10	7.20	7.31	8.10	8.20	8.31		(cm)	(cm)	(cm)	(cm)
	N4	39	−0.5	+0.5	+1.0	−0.2	−2.7	+12.1	+7.9	0.0	0.0	0.0	+0.5	−3.0	+0.9	+1.2	+0.4	+0.5	−0.1	+0.4	−0.1	+1.8	+3.5	−1.5	−3.0	23	30.7	11.1	41.8	+19.6
	3	131	+0.5	+6.5	+3.0	0.0	+5.0	+16.5	+2.0	0.0	+2.3	+1.2	−0.8	−3.6	−0.6	+0.3	−2.8	−1.8	−1.2	−0.8	−0.4	+1.2	−3.6	+4.4	+4.5	23	47.4	15.6	63.0	+31.8
	2	236	−1.1	+4.6	0.0	−0.5	0.0	−2.0	−1.0	−0.5	0.0	+0.4	+1.5	+4.1	+4.0	+3.0	+0.5	0.0	−0.5	+0.5	−0.5	+3.6	−0.7	+2.8	+0.5	23	25.5	6.8	32.3	+18.7
	1	341	−1.3	−5.7	0.0	−2.0	+1.0	−6.0	−1.0	−1.0	0.0	+0.1	+1.9	−0.3	−0.2	−0.1	+0.4	+2.7	+4.0	+4.5	−0.6	+4.4	−1.0	+5.6	+2.6	23	27.2	19.2	46.4	+8.0
1	T	396	−0.5	−2.1	−0.4	0.0	0.0	−1.3	−1.2	+0.5	0.0	+0.1	+13.9	−3.9	−0.1	−0.5	+0.5	+0.5	0.0	−0.7	+0.1	−1.4	−2.5	−3.0	+0.1	23	15.7	17.6	33.	−1.9
	S1	354	−1.0	−1.5	+0.5	−0.5	−0.5	−4.5	−0.7	−1.8	−0.5	−0.3	+0.1	−0.3	−0.4	−0.1	+0.1	+0.4	−0.3	0.0	0.0	−1.9	−4.3	−3.5	+1.5	23	2.6	22.1	24.7	−19.5
	2	257	−1.0	−0.9	+0.4	−0.5	0.0	−0.5	0.0	−0.5	0.0	−0.5	−0.5	−1.0	+0.2	0.0	−0.2	+0.5	+0.2	−0.2	0.0	−0.4	−5.1	+0.3	−0.8	23	1.6	12.1	13.7	−10.5
	3	154	+0.3	−1.7	+0.1	−0.2	−0.5	0.0	+0.5	−0.5	0.0	−0.4	−0.1	−0.1	+0.5	−0.4	+0.2	+0.2	−0.3	−0.1	0.0	−0.4	−0.7	+2.2	+0.4	23	4.4	5.4	9.8	−1.0
	4	76	+0.4	+0.3	+1.6	−0.7	+1.0	+1.0	+1.0	+2.0	+1.3	+0.8	+0.8	+3.1	+1.1	+2.4	+1.0	+1.5	0.0	+0.5	0.0	+1.0	−1.7	+1.8	−0.3	23	22.6	2.7	25.3	+19.9
	N4	18	−1.1	+0.8	+0.3	0.0	+2.0	+7.0	+9.0	+0.5	+1.5	+1.5	+2.5	−0.5	+.23	+2.2	+1.8	+1.8	+0.6	+1.8	+0.2	+1.8	+2.0	+3.2	+4.7	23	47.5	1.6	49.1	+45.9
	3	100	+0.2	+6.3	+2.0	+1.0	+5.5	+24.0	+9.0	+3.0	+3.0	+1.4	−1.7	−5.9	+1.7	0.0	−2.3	−1.2	−1.0	−1.0	−0.3	0.0	−6.2	△	△	21	57.1	19.6	76.7	+37.5
	2	206	−1.0	+7.2	+3.3	+1.0	+3.0	+6.0	−1.5	−1.0	+0.5	+0.2	+0.7	+1.3	−0.1	+0.4	+1.0	0.0	−0.2	+0.7	−1.0	+4.5	+1.4	+2.8	+1.1	23	35.1	4.8	39.9	+30.3
	1	312	−2.0	−1.0	−3.5	−1.5	−2.0	−5.0	−1.0	−0.5	0.0	0.0	+3.0	+4.1	−0.0	+2.0	+1.8	+0.5	+7.5	+1.0	−1.0	+15.0	+0.2	+7.6	+0.1	23	42.8	18.4	61.2	+24.4
2	T	396	0.0	+5.5	−2.5	+2.0	−1.0	−8.0	−5.0	−0.5	0.0	+0.9	+2.6	−0.2	−2.0	−1.8	+0.5	+1.0	−1.0	+0.7	−0.5	−2.3	−0.4	−2.2	0.0	23	13.2	27.4	40.6	−14.2
	S1	321	−1.0	−5.5	−2.5	0.0	−1.0	−11.0	−1.0	+0.5	−1.5	−0.3	−0.2	−2.0	−1.7	+0.2	0.0	+1.4	−1.5	−0.9	+0.1	−3.1	−4.0	−14.5	−1.0	23	2.2	52.7	54.9	−50.5
	2	225	−0.5	−2.2	−1.8	−0.5	−1.0	−8.0	0.0	0.0	−0.3	−0.7	+0.4	−0.9	0.0	−0.1	−0.2	+0.3	−0.9	+0.4	−0.2	−1.7	−2.6	△	△	21	1.1	21.6	22.7	−20.5
	3	128	0.0	−0.4	+0.1	−0.2	0.0	−0.5	0.0	0.0	−0.5	−0.1	+0.1	−1.2	+0.1	+0.1	0.0	+0.1	−0.1	−0.1	0.0	−0.7	+0.7	△	△	21	1.2	3.8	5.0	−2.6
	4	53	+0.5	+0.3	+0.2	0.0	+0.5	+0.5	+0.5	+1.5	+1.5	+1.2	+1.8	+3.0	+1.1	+0.4	+0.5	0.0	−0.4	−0.1	+0.1	+1.9	+1.7	△	△	21	17.2	0.5	17.7	+16.7
	N4	52	0.0	+1.7	+2.1	−0.5	+2.2	+6.0	+3.0	+5.5	+5.2	+2.7	+1.6	+10.7	−0.2	+2.5	+2.5	+0.8	+0.8	+2.1	−0.2	+4.8	+4.4	+1.8	+2.4	23	61.8	0.9	62.7	+60.9
	3	152	0.0	+2.2	+0.7	−0.4	+0.5	+4.7	+0.3	0.0	+0.2	−0.2	−0.4	+0.2	+0.2	−0.5	0.0	−0.6	+0.1	+0.4	−0.1	+1.7	+3.1	+1.7	+0.6	23	16.6	2.2	18.8	+14.4
	2	257	−0.7	+1.9	+2.3	−1.0	+1.0	+3.5	+2.0	−0.5	+1.5	0.0	−3.0	0.0	0.0	−0.2	−1.8	−1.6	+0.6	−0.5	−0.5	+4.0	+1.7	+2.9	−0.6	23	21.4	10.4	31.8	+11.0
	1	361	0.0	−1.5	−1.0	−0.5	+1.0	−1.0	0.0	0.0	−1.2	0.0	+4.2	+1.3	−0.3	−2.0	+0.6	+1.0	−1.6	+1.0	−1.0	−1.2	+0.1	+2.6	+1.3	23	13.1	11.3	24.4	+1.8
3	T	419	−0.5	−0.5	−1.0	+1.5	+0.5	−2.5	−1.5	0.0	0.0	+1.5	+9.0	−3.5	+0.4	−2.4	+1.4	+0.6	−1.1	+0.1	−0.6	+0.1	−3.7	−3.6	+0.3	23	15.4	20.9	36.3	−5.5
	S1	341	−2.0	0.0	+0.5	+0.5	0.0	−3.5	+0.5	−1.0	0.0	−0.2	+0.1	0.0	−0.5	−0.1	0.0	+0.7	−0.5	−0.3	0.0	+2.8	−5.5	−0.5	−1.3	23	5.1	15.4	20.5	−10.3
	2	243	−1.1	−1.9	0.0	+0.2	−0.3	−2.0	0.0	−0.5	0.0	−0.2	+0.4	−0.5	+0.2	−0.4	+0.5	+0.3	−0.4	−0.3	+0.1	−0.5	−0.7	−1.5	−0.5	23	1.7	10.8	12.5	−9.1
	3	240	−0.3	−0.7	−0.3	+0.2	−0.5	0.0	−0.5	−0.5	−0.2	−0.3	−0.2	−0.3	−0.2	0.0	+0.2	0.0	−0.3	−0.2	0.0	−0.5	−0.5	−0.2	−1.0	23	0.4	6.7	7.1	−6.3
	4	42	−1.0	+1.0	+0.3	+0.5	+1.2	−1.0	+1.5	0.0	+0.2	+0.4	+0.9	+2.5	+1.1	+0.4	+0.2	−0.2	+0.5	−1.5	+0.5	+1.5	+2.9	+2.6	0.0	23	18.2	3.7	21.9	+14.5
	N4	66	−1.0	−0.7	+0.2	−0.4	−0.1	−0.3	−0.5	−0.7	+0.1	0.0	-0.7	+0.6	−0.5	+0.3	+1.1	−1.4	+0.1	0.0	+0.1	+3.0	−0.5	+0.7	+0.6	23	6.8	6.8	13.6	0.0
	3	134	−1.0	−1.2	+0.2	−0.7	+0.2	−0.5	+0.1	−0.1	0.0	−0.4	−0.3	−0.1	−0.2	0.0	+0.5	−0.5	0.0	0.0	0.0	+0.3	−0.7	+0.4	0.0	23	1.7	5.7	7.4	−4.0
	2	197	0.0	−1.5	30.5	−0.6	+0.6	−1.4	+0.4	−1.0	+0.5	−0.2	−0.6	−0.2	+0.1	−0.1	0.0	−0.6	−0.2	0.0	+2.3	−1.8	−2.0	+0.3	+0.6	23	5.3	10.2	15.5	−4.9
	1	265	+1.0	−1.5	+0.5	−0.9	+0.9	−0.5	+0.5	−1.0	+0.1	+0.3	0.0	−4.6	+0.5	−0.1	0.0	0.0	−0.2	0.0	0.0	−0.2	−1.8	+0.8	+0.1	23	9.2	10.8	20.0	−1.6
4	T	411	−1.0	−2.0	0.0	−0.5	+0.5	−0.2	−0.8	+1.0	0.0	+0.5	+0.5	−3.5	+0.5	−0.1	+0.1	+0.3	−0.2	−0.1	0.0	−1.0	−4.0	+1.0	−2.3	23	8.9	15.7	24.6	−6.8
	S1	328	−2.1	−1.9	+1.0	0.0	0.0	−4.0	+1.0	−0.5	−0.5	+0.4	−0.2	−1.9	−0.1	−0.3	−0.2	+0.5	−0.5	−0.2	0.0	−0.2	−2.3	△	△	21	2.9	14.9	17.8	−12.0
	2	221	−0.3	−0.8	+0.6	+0.1	−1.1	−1.5	0.0	0.0	−0.3	−1.1	−0.1	0.0	−0.5	+0.2	+0.1	+0.3	0.0	−0.1	0.0	−0.5	−2.1	+0.9	−0.2	23	2.2	8.6	10.8	−6.4
	3	118	0.0	−0.2	+0.2	0.0	0.0	0.0	0.0	0.0	−0.5	0.0	+0.2	+0.5	−0.2	+0.5	+1.0	+1.1	0.0	+1.4	+0.3	−0.2	−2.4	+2.0	−0.7	23	7.2	4.2	11.4	+3.0
	4	28	+0.8	+0.6	+0.6	+0.1	+0.9	+1.0	+1.0	+0.5	+0.1	+1.1	+1.1	+2.2	+2.4	+1.6	+1.6	+1.6	+1.5	+1.5	+0.5	+0.5	+2.0	+2.9	−0.5	23	26.1	0.5	26.6	+25.6

H.G. : Height of Ground-surface N.M. : Number of Measuring A : Accumulation E : Erosion △ : Unmeasured

Table 2. The change of exposed pile length on artificial sand dure (1987. Jan. ~ Aug.)

No. 2

Line No.	Pile No.	H.G. (cm)	Change in high of measuring piles (cm) 1.31	2.14	2.22	2.28	3.14	3.21	3.28	4.5	4.10	4.20	4.30	5.10	5.20	5.31	6.10	6.20	6.30	7.10	7.20	7.31	8.10	8.20	8.31	N.M.	Σ|A| (cm)	Σ|E| (cm)	(cm)	(cm)
	W4	7	+0.1	+0.8	+4.8	+0.2	−0.2	−1.7	−0.3	).0	+0.7	+0.2	+0.1	+2.1	0.0	+1.3	+0.5	−0.1	+0.5	0.0	+0.1	+2.7	+3.1	+4.5	+2.0	23	23.7	2.3	26.0	+21.4
	3	99	−0.1	−0.2	+4.2	−0.1	−1.3	−2.5	0.0	−0.5	−0.1	−0.8	0.0	+0.4	−0.1	−0.5	−0.1	+0.5	0.0	+0.2	+0.6	−0.3	+5.2	+4.3	+0.8	23	16.2	6.6	22.8	+9.6
	2	199	−0.7	−1.6	+1.9	−0.2	−1.4	−2.5	−0.5	0.0	−0.2	+0.1	+0.1	+3.8	−2.3	−1.0	−0.5	+0.5	0.0	−0.3	+0.3	+1.7	+8.9	+0.6	−0.3	23	17.9	11.5	29.4	+6.4
	1	303	−1.5	−2.5	+0.5	0.0	+2.0	−4.0	−1.5	+0.5	+2.0	−2.0	+1.0	+5.2	−1.8	−0.9	−0.3	+0.3	−1.3	+0.3	+0.6	+1.2	+5.2	+1.7	+0.8	23	21.3	15.8	37.1	+5.5
5	T	417	0.0	+0.8	+1.7	−0.5	+5.0	+2.5	−1.5	+1.0	−0.2	+3.8	+2.2	−17.3	+3.5	+4.9	−3.4	+3.3	−3.1	+0.7	−1.7	−13.5	−15.5	−0.5	0.0	23	29.4	57.2	86.6	−27.8
	E1	309	−1.3	−0.7	+1.5	−0.5	−1.0	0.0	+1.0	−1.0	−1.0	−1.2	0.0	−6.8	+0.3	+0.2	−0.8	+0.8	−1.1	−0.7	+0.1	−0.6	−8.5	+0.9	0.0	23	4.8	25.2	30.0	−20.4
	2	210	−1.5	+1.5	+7.2	+0.3	−2.5	−3.0	−4.0	−1.5	−2.5	−0.4	+0.6	−2.9	+0.9	+3.3	−1.3	+1.0	+0.1	+0.2	0.0	+4.5	−11.4	−0.3	−2.3	23	19.6	33.6	53.2	−14.0
	3	106	−1.5	+3.5	+6.8	+1.2	+0.5	−3.5	−2.0	−1.5	+1.0	+2.3	−1.8	−0.2	−0.1	+1.8	−1.3	−0.2	+0.2	−0.7	+0.5	+3.2	−3.7	−0.5	0.0	23	21.0	17.0	38.0	+4.0
	4	27	−1.0	+7.3	+8.7	+0.5	+1.2	−0.7	0.0	0.0	+1.0	+0.2	−1.1	−0.1	−0.5	0.0	−0.7	−0.3	0.0	−0.5	−0.9	+0.5	−0.2	+2.8	+1.3	23	23.5	6.0	29.5	+17.5
	W4	0	+0.2	+1.1	+4.2	+1.0	+0.5	+3.8	+2.7	+4.5	+0.7	+1.0	−0.3	+3.6	+2.0	+1.0	+1.0	−0.1	+0.6	+0.1	+0.4	+6.8	+4.2	+22.	−1.1	23	41.6	1.5	43.1	+40.1
	3	91	−0.3	−2.6	+2.9	−1.0	−1.0	−1.0	0.0	0.0	0.0	−0.1	−0.1	+3.2	+1.8	+0.7	+1.5	0.0	+1.0	+0.4	−0.2	+8.8	+1.2	−0.1	+2.2	23	23.7	6.4	30.1	+17.3
	2	190	−0.5	−2.0	+2.9	−0.2	−1.3	−0.6	−2.9	0.0	−0.3	−1.3	+0.1	+8.5	−2.0	−0.7	−0.6	−1.3	−0.7	−1.2	+0.5	+7.2	+8.8	−0.8	+1.0	23	29.0	16.4	45.4	+12.6
	1	295	−3.0	−1.2	+1.7	0.0	−0.5	−3.0	−1.0	0.0	−1.5	−0.8	+0.3	+8.5	−2.8	−1.7	−1.2	−1.0	−0.8	−1.0	0.0	+8.0	+10.5	−1.1	−4.9	23	29.0	25.5	54.5	+3.5
6	T	424	0.0	+0.6	−0.6	0.0	+0.5	+5.5	−3.7	+0.7	0.0	+2.4	+2.8	−20.2	+4.6	+5.4	−2.2	+8.8	−4.6	+8.0	−3.0	−23.0	−18.2	−3.0	+6.9	23	46.2	78.5	124.7	−32.3
	E1	313	−2.0	−1.0	+25.	+0.5	+2.0	+2.0	−3.5	−1.0	−3.0	−0.5	+0.5	−3.0	−0.4	+0.7	−1.8	−0.4	−0.6	−0.1	−0.3	−8.6	−9.0	+2.0	0.0	23	10.2	35.2	45.4	−25.0
	2	212	−0.5	+4.5	+7.4	+0.6	−2.0	−0.5	+0.5	−0.5	0.0	+0.5	−0.3	−6.6	+2.2	+3.2	−0.8	−0.2	+1.0	0.0	0.0	−0.5	−9.5	−5.8	+2.9	23	22.8	27.5	50.0	−4.4
	3	107	+0.1	+4.1	+6.0	+1.3	+1.0	+2.5	+1.5	−4.5	+2.0	+2.2	0.0	−0.1	+2.6	+1.7	−1.0	−0.2	+1.2	−0.5	+0.2	−0.2	−4.5	+0.5	+1.0	23	27.9	11.0	38.9	+16.9
	4	16	+1.2	+4.3	+7.0	+0.5	+2.0	+5.0	+2.5	+1.5	0.0	−0.3	+0.5	−0.3	+0.6	−0.3	−0.5	+0.2	+0.9	−0.8	+0.4	+0.2	+0.8	+1.2	+2.2	23	31.0	2.2	33.2	+28.8
	W4	35	+0.2	0.0	−1.7	−0.5	−1.0	−4.0	0.0	−0.5	+0.3	−0.3	+0.2	+14.4	+1.7	+0.2	+4.5	+2.1	+1.2	+0.9	−0.2	−1.1	+4.6	+0.3	−3.3	23	30.6	12.6	43.2	+18.0
	3	105	−0.5	−1.1	−1.4	0.0	−1.5	−0.5	0.0	−0.5	+0.5	+0.5	+0.2	+2.3	−0.3	−1.7	+0.5	+1.0	−0.8	−1.1	+0.4	−0.8	+1.8	+1.0	+1.5	23	9.7	10.2	19.9	−0.5
	2	209	−0.5	−0.5	−1.0	−0.2	−0.8	−1.5	−0.5	−1.0	+0.3	−0.1	+0.1	+5.2	−2.5	−1.9	−0.9	−0.4	+0.9	−1.0	+0.1	+1.0	+6.7	−7.0	−1.2	23	14.3	21.0	35.3	−6.7
	1	313	−0.8	−1.7	−0.5	−0.2	+0.2	−2.0	−2.0	−0.5	−0.5	−0.5	0.0	+5.1	−3.6	−1.0	−0.5	−1.0	−1.5	−0.4	+0.1	+1.5	0.0	−0.5	+7.5	23	14.4	17.2	31.6	−2.8
7	T	384	−1.0	−1.2	+0.2	−0.5	−3.0	+5.5	−1.5	+0.5	−2.0	+1.4	+1.3	−12.1	+1.0	−0.1	−0.7	+2.7	−1.5	+1.4	−0.3	−7.3	−11.3	−2.5	−1.5	23	14.0	46.5	60.5	−32.5
	E1	365	−0.2	−0.8	−0.0	−0.5	+0.5	−1.0	+0.5	−0.5	0.0	−0.8	+1.8	−6.0	+0.4	+0.6	−0.6	+0.1	−0.5	−0.2	+0.2	−4.4	+2.7	−10.6	−1.2	23	6.8	27.3	34.1	−20.5
	2	236	+0.2	−2.4	−1.4	−0.5	−2.9	0.0	+2.0	−3.0	+1.0	−2.7	−0.5	−2.8	+1.5	−2.2	+0.1	+1.3	+0.8	−1.0	+0.4	−3.7	−2.4	+1.2	−0.8	23	8.5	26.3	34.8	−17.8
	3	128	+1.2	−0.2	−0.6	−0.6	−0.3	−1.5	+1.5	−1.5	−3.5	−0.9	+0.1	−0.2	0.0	−0.3	+0.3	0.0	+0.1	−0.9	+0.9	−1.5	−0.9	+0.9	+0.6	23	5.6	12.9	18.5	−7.3
	4	33	−0.3	−0.7	+1.0	−0.5	0.0	+0.5	+3.0	−2.5	0.0	+0.2	+0.2	+0.6	−1.0	+0.3	+0.7	0.0	0.0	−0.5	0.0	−0.8	+0.2	+1.6	+0.7	23	9.0	6.3	15.3	+2.7

H.G. : Height of Ground-surface N.M. : Number of Measuring A : Accumulation E : Erosion

Table 3. Additional change length of each measured pile on the artificial sand dune

(Dec., 1986 – Aug., 1987)

(cm)

Direction / Measurement point	Southwest side 4	3	2	1	Top of dune	Northeast side 1	2	3	4
Line No. 1	41.8	63.0	32.3	46.4	33.3	24.7	13.7	9.8	25.3
No. 2	49.1	76.7	39.9	61.2	40.6	54.9	22.7	5.0	17.7
No. 3	62.7	18.8	31.8	24.4	36.3	20.5	12.5	7.1	21.9
No. 4	13.6	7.4	15.5	20.0	24.6	17.8	10.8	11.4	26.6
No. 5	26.0	22.8	29.4	37.1	86.6	30.0	53.7	38.0	29.5
No. 6	43.1	30.1	45.4	54.5	124.7	45.4	50.0	38.9	33.2
No. 7	43.2	19.9	35.3	31.6	60.5	34.1	34.8	18.5	15.3
Mean value		36.5			45.2			24.6	

Table 4. Captured amounts of blowing sand at different heights from ground surface in the artificial sand dune

Site	Heights of ground surface (m)	(1987) Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Total (%)
		Captured amounts of sand (gr/100 cm²)							
Foot of south side (windward)	0.2	33.0	154.1	513.4	396.1	245.1	178.6	198.8	1719.1 (95.6)
	0.5	1.7	3.1	21.7	6.8	10.3	14.0	12.9	70.5 (3.9)
	1.5	0.2	0.3	2.1	1.0	1.3	1.6	1.4	7.9 (0.4)
	Total	34.9	157.5	557.2	403.9	256.7	194.2	213.1	1797.5 (99.9)
Top of sand dune	0.2	2.1	266.3	1023.9	225.9	115.0	238.4	128.9	2000.5 (64.2)
	0.5	0.8	115.3	363.7	331.9	21.4	24.2	44.6	901.9 (29.0)
	1.5	0.2	3.7	189.7	15.3	1.6	0.8	0.3	211.6 (6.8)
	Total	3.1	385.3	1577.3	573.1	138.0	263.4	173.8	3114.0 (100)
Foot of north side (leeward)	0.2	10.9	194.9	836.1	151.8	175.7	135.4	261.0	1765.8 (80.1)
	0.5	1.0	45.9	243.7	18.9	20.8	11.7	15.9	357.9 (16.2)
	1.5	0.2	14.3	55.5	2.8	2.7	2.3	2.6	80.4 (3.6)
	Total	12.1	255.1	1135.3	173.5	199.2	149.4	279.5	2204.1 (99.9)

+ Uncertain value

Table 5. The time schecule of the experiment .

Treatments	Execute time	Contents of observation
1. Construction of sand dune	Sep., 1986	
2. Construction of sand fence on the top of sand dune	Dec., 1986	
	Dec., 19986 – Sep., 1987	Effects of sand fence a. Topographic change of the sand (Measuring pile) b. Amount of blowing sand (Capture instrument of rolling type)
3. Removement of sand fence	Oct., 1987	
	Oct., 1987 – Mar., 1988	Non-treatment condition after removement of the fence a. Topographic change of the sand (Measuring pile) b. Amount of blowing sand (Capture instrument of rolling type) c. Wind speed
4. Mulching and tree planting	Apr., 1988	
	Apr., 1988 – Mar., 1989	Effects of mulching and covering by vegetation a. Topographic change of the sand (Measuring pile) b. Amount of blowing sand (Capture instrument of rolling type) c. Wind speed d. Growth of vegetation

(2) Observation of Natural Sand Dune Movement

ABSTRACT

Sand dune movement was observed in a typical natural sand dune area in Al Oha, UAE.

Dune erosion was recognized in windward slope, and shifting sand deposited in leeward slope.

The total amount of blowing sand at 0.2 m high were 64.97 kg/100 cm^2 and 18.02 kg/100 cm^2 at the top of dune and the north foot of dune, respectively, which was measured from January to July in 1987. The amount of captured sand was the largest in April at the top of dune, but in March at the north foot of dune during the observation period.

INTRODUCTION

Sand movement is major obstruction to the agriculture in desert regions. Few studies, however, have been done about the sand dune movement in UAE. This observation was conducted in order to investigate the movement of natural sand dune, which is useful for the sand dune fixation.

MATERIALS AND METHODS

A typical natural sand dune was selected to observe the sand dune movement in the neighbouring area to the University Farm in Al Oha, UAE. The size of the sand dune was 190 m in length and 3 m in height as shown in Figs. 7 and 8.

Short-term topographic chnge and amount of blowing sand were measured every 10 days. Long-term topographic change was measured in September 1986, April and September 1987. The details of methods are mentioned in "Experiment of Sand Dune Fixation".

RESULTS AND DISCUSSION

The change of exposed length of each pile are shown in Tables 6 and 7, and the additional change length of fixed piles are arranged by absolute value as shown in Table 8. It shows that topographic change of the sand dune top was more remarkable than the foot of both sides of dune in all measurement lines. The mean values were 254.2 cm, 66.2 cm, and 40.3 cm at the top of sand dune, at the windward foot (south side) and at the leeward foot (north side), respectively. The prevailing wind didrection was south-southeast during the observation period.

The change in cross section of the sand dune is shown in Fig. 9. Dune erosion was recognized in south slope which was windward side, and shifting sand deposited in north slope which was leeward.

The amount of blowing sand at different heights from ground surface is shown in Table 9. Originally the sand capture equipments were set at three different points, which were at the top, south and north foot of the sand dune, respectively. Some of the equipments, however, were stolen in February 1987. Therefore, Table 9 shows the limited results which were available in the observation area. The total amount of blowing sand at 0.2 m high were 64.97 kg/100 cm^2 and 18.02 kg/100 cm^2 at the top of sand dune and at the north foot, respectively, which was measured in seven months during from January to July in 1987. At the top of the sand dune, the amount of captured sand was the largest in April (28.93 kg/100 cm^2). At the north foot of the dune, in contrast, that amount was the largest in March (3.63 kg/100 cm^2).

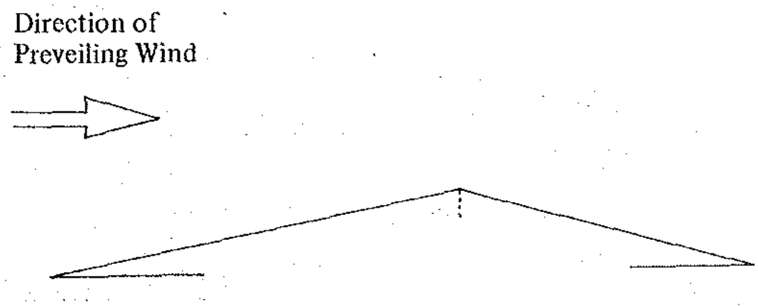


Fig. 7 Typical cross section figure of the natural sand dune

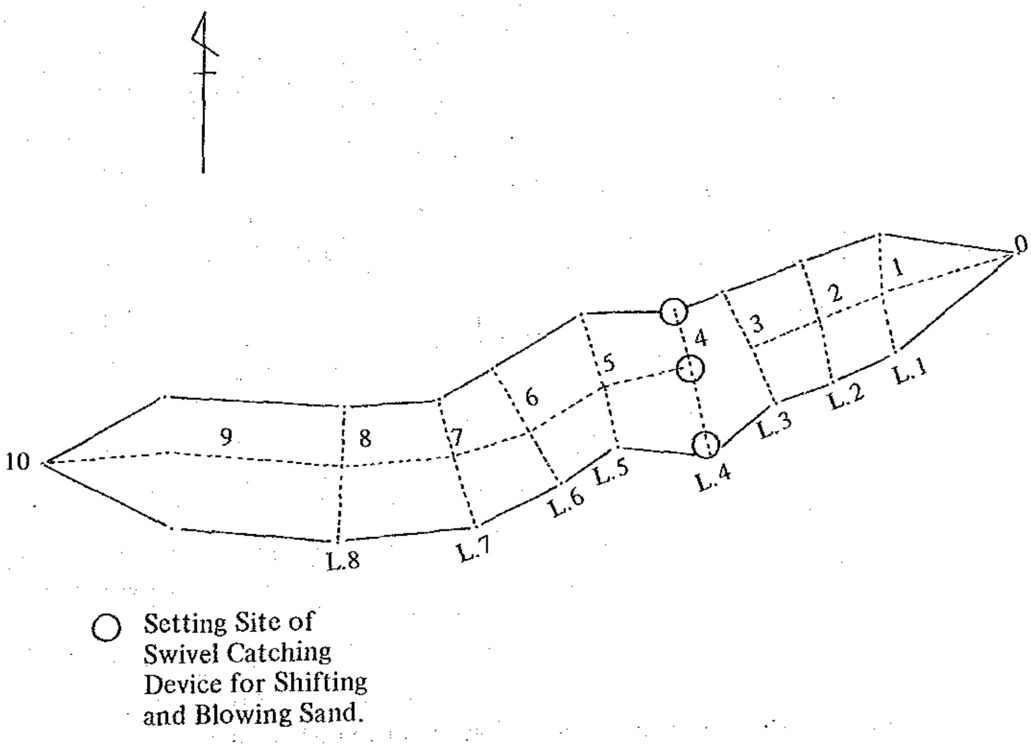


Fig. 8 Plane figure of the natural sand dune

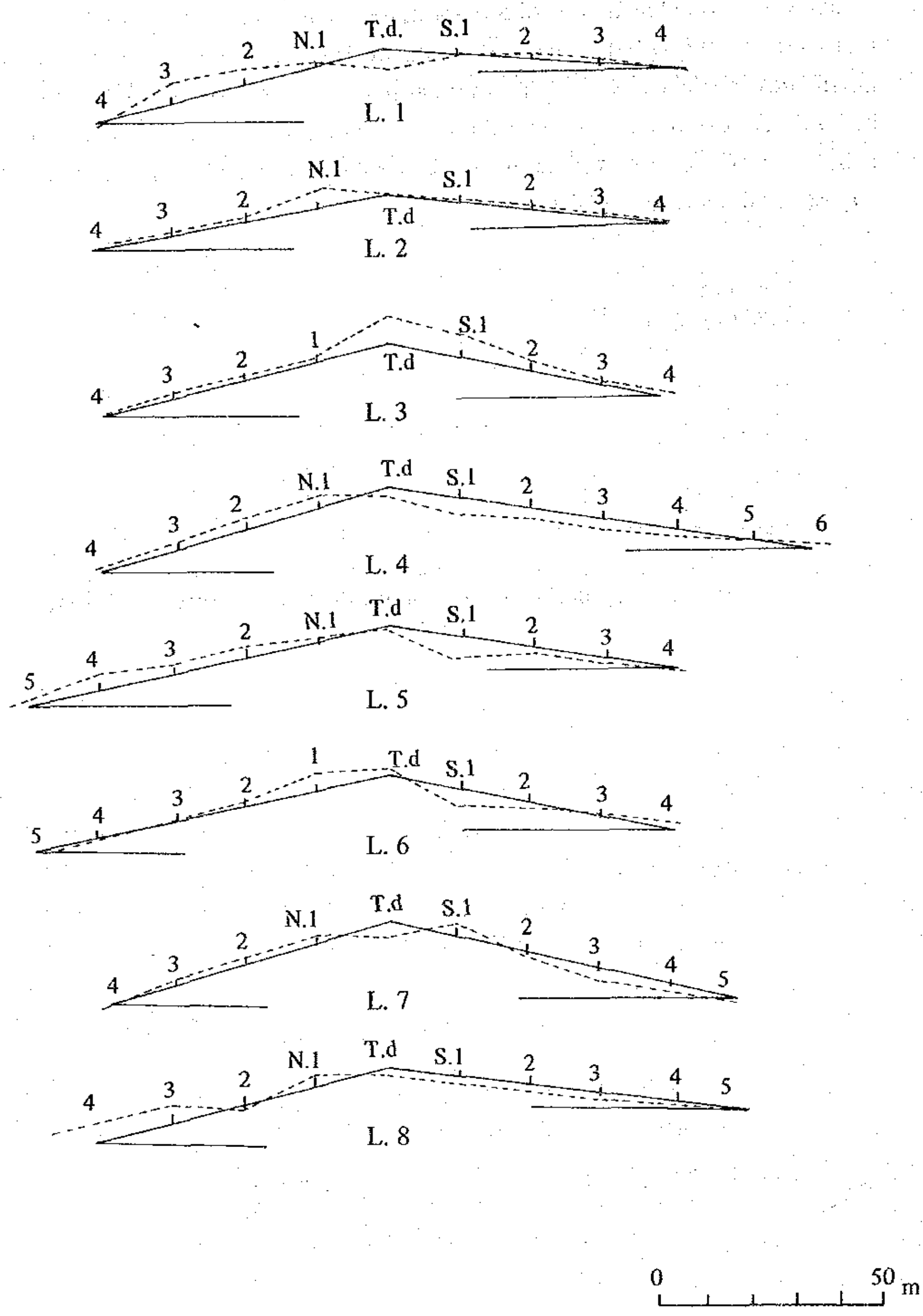


Fig. 9 Change of the cross section of natural sand dune

Table 6. The change of exposed pile length on natural sand dure (1987. Jan. ~ Aug.)

No. 1

Line No.	Pile No.	H.G. (cm)	1.31	2.14	2.22	2.28	3.14	3.21	3.28	4.5	4.10	4.20	4.30	5.10	5.20	5.31	6.10	6.20	6.30	7.10	7.20	7.31	8.10	8.20	8.31	N.M.	Σ|A| (cm)	Σ|E| (cm)	(cm)	(cm)
			Change in high of measuring piles (cm)																											
	N4	112	−0.1	−1.0	−2.0	−2.5	+0.1	−0.5	−3.4	−1.8	−0.6	−1.4	−0.1	−0.9	−1.3	+6.5	+10.7	+13.5	+3.2	+8.4	−27.8	−6.3	−12.0	−2.4	−0.5	23	42.4	64.6	107.0	−22.2
	3	157	−0.5	+2.5	+3.9	−0.7	+7.8	+2.1	+4.9	+13.7	+6.4	+8.6	+1.2	−6.7	+16.5	+18.0	+3.5	−2.5	−1.2	+4.2	−0.5	+5.5	−16.0	+1.2	+5.5	23	105.5	28.1	133.6	+77.4
	2	276	−3.5	+4.4	+8.0	+0.4	+20.5	+11.5	+7.5	+12.5	−17.9	+8.2	−2.6	−5.5	+19.1	+13.4	−18.0	−10.5	−8.6	+2.1	−3.6	+32.6	−10.3	+8.5	+1.8	23	150.5	80.5	231.0	+70.0
	1	391	−0.5	+9.5	+16.5	+2.5	+24.0	−11.5	−5.5	−4.0	−11.5	−2.3	+15.8	−1.0	−8.8	−5.2	+29.0	−10.4	−13.0	+1.7	−5.3	+9.2	−15.7	−6.0	+3.0	23	111.2	100.7	211.9	+10.5
1	T	452	−6.1	+6.8	−23.5	−0.6	−23.2	−4.0	−11.5	−1.5	−5.5	−4.6	+0.8	+2.0	−6.1	−3.2	−0.4	+11.9	+35.6	+15.7	+14.0	−67.7	−3.5	−5.3	−0.6	23	86.8	167.3	254.1	−80.5
	S1	403	+18.0	−38.0	−15.0	−0.2	−9.8	−2.2	−3.8	+4.3	−3.6	−2.2	−0.8	+0.9	−1.8	−1.4	−2.6	−2.7	−2.4	−3.2	+9.2	−7.8	+4.7	0.0	−0.5	23	37.1	98.0	135.1	−60.9
	2	336	−1.9	+1.5	+0.4	−0.5	−0.7	+0.1	+4.0	−0.5	+0.5	+0.5	−0.8	+0.5	−0.4	2.5	−1.4	−2.4	−1.0	−2.4	−0.9	+2.2	+4.1	+0.6	−0.9	23	14.4	16.3	30.7	−1.9
	3	333	−1.2	+1.4	+4.7	−0.5	+21.1	−1.4	+1.3	−0.7	+1.7	+0.1	−1.7	+0.2	+0.4	−2.3	−3.7	−3.4	−2.0	−0.9	+0.1	−0.1	+2.8	+0.8	−0.9	23	34.6	18.8	53.4	+15.8
	4	353	−2.1	+4.1	+4.7	−1.3	+4.3	−1.7	−0.0	+6.5	−0.5	−2.3	−2.5	+0.8	−2.2	−5.1	−2.8	−4.1	−3.6	−3.6	−1.4	+0.9	+2.7	+0.5	−0.5	23	24.5	33.7	58.2	−9.2
	N4	115	+0.1	−0.3	0.0	−0.5	+0.9	+1.1	−1.3	+0.2	0.0	0.0	−0.5	−2.2	+0.3	−0.2	−1.7	+0.1	−0.4	−0.3	−0.3	−0.3	+0.2	+0.6	+0.4	23	3.9	8.0	11.9	−4.1
	3	215	−0.9	+0.6	+0.8	−1.0	+4.0	+0.5	+0.5	+3.4	+0.5	+0.2	−0.1	−1.6	+1.2	0.0	−0.6	−1.3	−0.5	−1.2	+0.4	−0.5	−0.4	0.0	+0.1	23	12.2	8.1	20.3	+4.1
	2	255	−1.2	+1.2	+2.2	−1.8	+14.7	−0.1	+10.3	+16.0	+7.9	−10.8	−8.0	+9.5	−0.4	−2.2	−6.5	−9.7	−5.1	−3.4	−0.3	−1.4	−12.8	+12.8	+1.5	23	76.1	63.7	139.8	+12.4
	1	306	−4.6	+6.7	+40.5	+1.8	+22.1	+2.6	−0.4	+21.0	+4.0	+23.5	−24.5	+12.3	+0.8	−7.0	−15.9	−15.0	−7.8	−3.8	−2.9	+24.8	+35.1	−2.6	−12.7	23	195.2	97.2	292.4	+98.0
2	T	373	−19.4	+23.2	−19.4	+1.8	−14.2	+2.5	−2.8	−2.3	−6.9	+2.9	+7.0	−11.7	+11.1	+8.1	+25.9	+51.0	−14.9	−0.4	−3.9	−12.1	−16.1	−5.3	+2.0	23	135.5	129.4	264.9	+6.1
	S1	303	−13.2	−16.4	−6.8	+1.2	−6.2	+2.9	−4.1	−7.8	−0.2	+2.7	+7.4	−6.6	+7.4	+3.8	+7.0	+12.5	+4.4	+17.8	+3.4	−17.4	−7.3	−5.0	−0.8	23	83.7	78.6	162.3	+5.1
	2	229	−6.8	10.6	+3.4	−0.4	−0.3	+1.1	−0.7	−6.8	+0.1	+2.1	+6.5	−1.8	+4.1	−0.3	+4.6	+3.9	+0.1	−1.0	+1.0	−2.2	−1.3	−0.9	−0.3	23	37.5	22.8	60.3	+14.7
	3	215	−3.5	−4.1	−0.3	+0.2	+1.7	+0.9	+2.0	+0.6	+0.5	+1.2	+0.9	+1.5	+3.9	+1.5	+0.3	−2.7	−1.3	−2.6	−0.5	−0.8	−0.9	+3.5	+1.2	23	19.9	17.7	37.6	+2.2
	4	230	−1.2	+0.4	+1.9	−0.4	+5.3	+1.9	+2.7	+11.5	+4.4	+2.4	−4.3	+0.6	+2.2	−0.8	−3.9	−6.5	−1.4	−4.0	0.0	+5.1	−0.4	+2.2	−0.7	23	40.6	23.6	64.2	+17.0
	N4	135	−0.2	+0.1	+0.5	−0.6	+1.3	+0.7	+0.9	+1.4	+0.8	−1.5	+0.6	−0.8	0.0	−0.2	−1.5	+0.1	−0.2	+0.1	+0.2	−0.5	−0.1	−0.6	−0.3	23	6.7	6.5	13.2	+0.2
	3	169	−1.1	−0.5	+4.6	−0.7	+2.8	+0.4	+2.0	+4.6	+0.5	+0.1	−1.2	+0.9	+0.6	−0.9	+0.3	−1.2	+0.1	−1.1	+0.7	+0.5	+0.7	+0.7	−0.1	23	19.5	6.8	26.3	+12.7
	2	245	−1.7	+3.2	+5.0	−1.5	+8.7	+1.8	+1.7	+8.9	+4.7	+1.8	−3.7	+2.8	+1.7	−0.8	−4.9	−10.3	−1.9	−3.3	−1.2	+3.8	+1.9	+1.9	−0.7	23	47.9	30.0	77.9	+17.9
	1	348	−6.6	+6.6	+34.5	+0.3	+3.45	−4.8	+2.8	−3.6	+13.7	−6.1	−28.8	+0.3	+0.7	−12.5	−13.7	−18.1	−3.5	−5.2	−3.6	+19.2	+20.6	+5.6	−9.8	23	138.8	116.3	255.1	+22.5
3	T	429	−10.4	+6.8	−15.5	+4.7	−14.1	+2.9	−0.7	+6.3	−11.0	+2.9	+59.0	+37.4	+34.0	−15.4	−4.3	−22.2	+4.8	−7.6	−4.5	+33.4	−11.3	−0.6	+30.2	23	220.4·	117.6	338.0	+102.8·
	S1	338	+2.1	−11.3	−9.0	+0.9	−8.6	+2.5	−1.1	−0.7	−3.9	+3.5	+10.5	−2.9	+6.9	+16.1	+30.9	+61.0	+4.7	+6.5	+0.4	Δ	−8.8	−5.0	−2.1	22	146.0	53.4	199.4	+92.6
	2	242	−0.8	−4.9	−3.1	+0.4	−0.6	+0.6	+1.1	−1.5	+1.0	+1.9	+8.6	−3.2	+8.3	+7.3	+2.4	+8.9	+6.4	+15.1	+14.8	−17.4	−5.5	−4.3	+0.9	23	77.7	41.3	119.0	+36.4
	3	183	−2.0	+4.1	+3.2	−0.1	+2.7	+0.5	+1.4	+9.1	+2.7	+0.6	−1.4	0.0	+2.3	−0.1	−1.0	−4.3	+0.7	−1.6	−1.8	+6.2	+1.0	+3.2	+0.4	23	38.1	12.3	50.4	+25.8
	4	188	−1.3	+2.1	+0.4	−0.1	+11.8	−0.8	+1.1	+4.3	+1.6	−0.5	−0.7	0.0	−1.3	−1.6	−0.6	−0.6	−0.4	−0.1	−0.1	+1.3	+1.7	+3.6	−0.2	23	27.9	8.3	36.2	+19.6
	N4	121	−0.8	−0.8	+1.8	−0.4	+7.1	−0.5	−0.1	+3.0	+0.9	−1.2	−1.2	−0.0	−1.0	0.0	−1.0	−0.4	−0.3	−1.0	−0.2	+2.3	−0.7	+1.0	−0.3	23	16.1	9.9	26.0	+6.2
	3	181	−1.6	+1.6	+3.3	−0.6	+11.3	−1.5	+2.4	+7.6	−0.2	−0.7	−1.0	+3.9	−1.2	−1.9	−0.9	−1.2	−1.8	−0.4	+0.5	+1.4	+0.1	+2.0	+0.9	23	35.0	13.0	48.0	+22.0
	2	261	−1.8	+1.8	+11.5	+0.2	+24.5	+6.8	+13.0	+19.2	+5.5	+1.8	−13.3	−5.7	+3.0	+7.6	−13.7	−12.3	−5.1	0.0	−1.1	+4.0	+2.2	+2.2	+1.5	23	104.8	53.0	157.8	+51.8
	1	386	−25.0	+29.5	+34.5	−2.0	+33.1	+1.6	+5.1	−16.4	+7.0	+5.2	−35.8	+13.8	+16.6	−2.8	−27.3	−23.9	−6.1	+1.6	−3.6	+54.8	−7.0	+6.3	−9.3	23	209.1	159.2	368.3	+49.9
4	T	446	−14.0	+25.0	−16.8	+6.4	−16.6	−3.0	−4.9	−3.0	−4.2	−1.8	+32.3	−9.0	−19.5	−5.5	+38.0	+4.7	+7.7	−7.2	−0.4	−32.4	−13.5	+3.0	−2.5	23	117.1	154.3	271.4	−37.2
	S1	411	+24.5	−35.5	−15.9	+2.0	−11.5	−2.8	−1.7	−3.5	−2.3	−2.4	−6.8	+2.0	−0.6	−3.9	−6.2	+5.2	+6.6	+3.2	+3.3	−10.8	+4.0	−1.7	+0.2	23	51.0	105.6	156.6	−54.6
	2	342	−1.3	−4.5	−4.5	−1.1	−3.6	−1.4	+0.9	−5.3	−1.6	−0.3	−0.6	+0.3	−1.8	−3.2	−3.6	−2.3	−7.0	+2.5	−1.3	−0.4	+5.6	−0.7	−0.9	23	9.3	45.4	54.7	−36.1
	3	291	−4.8	−0.4	−0.9	−1.0	−0.8	−0.2	−0.9	−7.1	−1.6	−0.8	+2.3	−0.7	−0.1	−3.0	−1.3	−2.3	−5.4	−2.8	−2.0	−0.6	+3.9	−1.0	−0.9	23	6.2	38.6	44.8	−38.6
	4	251	−2.9	−1.1	−1.8	−0.3	−5.3	0.0	−1.2	−4.4	−2.5	−0.9	+2.4	+0.5	−1.4	−0.7	+0.3	−0.7	−3.9	+7.9	−10.9	+0.7	+3.8	−0.9	−0.5	23	15.6	39.4	55.0	−23.8
	5	209	−7.5	+7.5	−2.3	−0.2	+1.0	Δ	Δ	−4.1	−1.7	+0.9	+2.4	0.0	+1.4	+3.1	+1.6	+1.1	−0.6	−0.9	−1.0	+1.0	+2.5	−0.6	−0.2	21	22.5	19.1	41.6	+3.4
	6	159	Δ	Δ	Δ	Δ	Δ	Δ	+0.4	+3.1	+0.7	+0.8	+3.0	−1.6	+2.9	+4.2	+2.4	+3.3	−0.8	+0.9	0.0	−0.7	+0.1	−1.0	0.0	17	21.8	4.1	25.9	+17.7

H.G. : Height of Ground-surface N.M. : Nubmer of Measuring A : Accumulation E : Erosion Δ : Unmeasured • : Uncertain value

Table 7. The change of exposed pile length on natural sand dure (1987. Jan. ~ Aug.)

No. 2

Line No.	Pile No.	H.G. (cm)	Change in high of measuring piles (cm) 1.31	2.14	2.22	2.28	3.14	3.21	3.28	4.5	4.10	4.20	4.30	5.10	5.20	5.31	6.10	6.20	6.30	7.10	7.20	7.31	8.10	8.20	8.31	N.M.	Σ|A| (cm)	Σ|E| (cm)	(cm)	(cm)
	N5	36	−0.1	+0.1	0.0	0.0	+0.7	+0.3	0.0	+0.5	+0.4	−0.4	+0.1	−1.0	+3.1	+0.3	+0.8	+1.0	−0.1	−0.4	+0.2	+0.6	+1.7	+1.0	+0.6	23	11.4	2.0	13.4	+9.4
	4	88	−1.1	+1.3	+1.8	−0.2	+9.9	+0.2	+4.4	+16.2	+2.9	+0.5	−2.4	+2.9	+6.6	+4.4	+4.9	−6.2	+1.5	−3.7	−0.7	+14.7	−12.5	+2.0	−1.1	23	74.2	27.9	102.1	+46.3
	3	214	−2.2	+8.2	+2.5	−1.3	+18.8	+0.6	+27.1	+4.2	+16.0	−0.8	−17.4	−5.1	−3.9	−4.5	−8.0	−7.2	−1.8	−1.4	−1.2	−0.4	+1.8	+2.8	+0.4	23	82.4	55.2	137.6	+27.2
	2	285	−6.5	+5.5	+25.3	+2.8	+30.7	−0.2	+2.2	−10.4	+2.2	−1.3	−14.9	+4.2	+3.0	−5.8	−13.5	−14.3	−3.8	−2.2	−2.5	+16.7	+35.2	+4.6	−17.3	23	132.4	92.7	225.1	+39.7
	1	333	−9.9	+18.9	+17.0	−1.4	−8.9	−1.4	−3.4	−0.2	−5.0	+4.8	+7.8	+25.7	+11.7	−1.6	−22.1	−17.9	−7.5	−4.5	−3.4	+28.7	−5.6	−1.2	+7.3	23	121.9	94.0	215.9	+27.9
5	T	344	−5.0	+6.2	−19.5	+1.8	−14.3	−1.5	−5.8	−4.9	−4.0	−1.1	+32.4	−26.5	−4.1	+1.0	+24.6	+51.0	−12.4	−2.3	−5.2	−19.3	−8.1	−6.2	+12.3	23	129.3	140.2	269.5	−10.9
	S1	306	+11.4	−30.2	−17.6	+0.8	−9.7	−0.9	−4.5	−6.3	−1.5	−1.9	−1.0	+0.2	+0.5	+1.4	−4.9	+16.0	+22.4	+17.3	−21.7	−48.8	−4.1	−5.9	−0.2	23	70.0	159.2	229.2	−89.2
	2	235	−1.7	−4.5	−5.8	+0.6	−7.6	0.0	−3.1	−2.9	−3.0	−2.0	+1.6	−0.7	−0.3	−2.0	−2.5	−1.5	−3.0	+3.7	+2.1	−1.7	+2.5	−0.9	−0.3	23	10.5	43.5	54.0	−33.0
	3	191	−1.0	−3.0	−1.7	0.0	−6.6	−0.2	−1.0	−3.5	+0.6	−1.6	+3.3	−1.5	+1.7	−3.5	−0.5	−3.8	−1.0	−7.2	+0.3	+1.4	+2.6	+2.2	−0.4	23	12.1	36.5	48.6	−24.4
	4	165	−0.2	−1.0	+0.1	−0.3	−4.3	−0.6	−0.1	−1.9	+1.1	−1.7	−1.3	+1.0	+1.8	−4.4	+3.1	+2.6	−1.6	−1.9	−1.8	+0.8	0.0	+1.7	−1.2	23	12.2	22.3	34.5	−10.1
	N5	71	−0.5	−2.1	+0.5	−0.2	−1.4	−0.1	−0.4	−2.2	+0.9	−0.9	0.0	−1.5	−0.3	+0.3	−0.5	−0.5	−0.5	+0.3	0.0	−0.5	−1.5	+0.4	+0.1	23	2.5	13.1	15.6	−10.6
	4	53	−0.7	−1.6	+0.1	−0.4	−2.3	−0.3	0.0	−0.8	+0.5	−1.0	−0.4	−0.2	−0.1	−0.2	−1.1	−10.4	+8.4	−0.7	+0.1	+0.6	−1.3	−0.5	+0.2	23	9.9	22.0	31.9	−12.1
	3	88	+0.2	−1.1	+0.2	+0.2	+3.0	+0.4	+2.6	+3.8	+0.4	−0.5	−0.9	+1.5	+0.5	−0.7	−0.7	−13.7	+9.3	−1.1	+0.4	−0.8	−2.0	+0.2	+0.6	23	23.3	21.5	44.8	+1.8
	2	158	−2.3	+3.2	+3.6	−0.2	+13.5	+0.8	+3.8	+8.3	+5.3	−2.9	−7.7	−2.8	+1.5	−1.3	−6.2	−11.5	−3.4	−3.6	0.0	+0.2	+29.8	−7.0	+0.7	23	70.7	49.9	120.6	+20.8
	1	258	−11.0	+13.0	+50.5	−9.3	+36.3	−15.0	+15.1	+8.5	+11.9	+8.6	−10.1·	+10.1	+0.2	−11.6	−15.5	−22.5	−5.7	−7.0	−1.7	+12.0	+27.2	+6.0	−12.4	23	199.4	121.8	321.2	+77.6
6	T	319	−8.1	+9.6	−17.0	+1.8	−14.2	+3.4	−8.1	+9.3	−14.2	+0.3	+70.4	−22.5	+3.6	−0.2	+3.6	−26.5	−3.1	−11.5	−5.4	+40.1	−9.3	+1.1	+24.9	23	168.1	140.1	308.2	+28.0
	S1	259	+9.6	−15.4	−14.7	−1.1	−16.8	−0.5	−5.4	−5.4	−3.9	+0.5	+1.7	−5.0	+10.0	+10.6	+20.6	Δ	+15.1	+5.9	−1.5	−65.7	−6.9	−4.6	−1.5	22	74.0	148.4	222.4	−17.4
	2	196	+1.5	−3.3	−18.7	−0.4	−13.9	−0.6	−0.7	−6.2	−1.2	−1.8	−9.0	−5.1	−5.6	−5.6	+0.2	+33.0	+12.0	+20.7	+15.2	−14.8	−4.8	−3.9	+3.7	23	86.3	95.6	181.9	−9.3
	3	113	−0.6	−0.6	−0.1	+0.4	−0.1	−0.2	+1.1	−1.9	−1.5	−0.4	+1.9	+0.9	+1.5	+1.9	+0.6	Δ	+2.8	−10.1	+0.6	+0.5	−0.1	+2.7	0.0	22	14.9	15.6	30.5	−0.7
	4	113	−1.2	+0.3	+1.9	−0.8	+22.8	+4.7	+10.6	+34.3	+7.2	+2.8	−22.5	+5.6	+6.2	+0.8	−14.1	−19.6	−6.7	−7.4	−8.5	+5.6	+2.4	+6.4	+1.4	23	113.0	80.8	193.8	+32.2
	N4	7	−0.1	−0.8	+0.4	−0.5	+0.1	+1.1	−0.4	+0.9	−0.5	−0.7	+0.6	−2.5	+0.9	−0.4	+0.6	−0.5	+1.0	+0.6	−0.4	−1.2	−0.6	+0.5	+0.7	23	7.4	8.7	16.1	−1.3
	3	59	0.0	+1.5	+0.9	−1.0	+6.3	+0.9	+1.0	+5.7	+2.0	−1.2	+0.1	−1.4	+0.7	−0.1	+0.3	−0.5	+0.3	−0.7	+0.1	−0.9	−2.0	0.0	+0.2	23	20.0	7.8	27.8	+12.2
	2	154	−3.0	+4.0	+6.5	Δ	+20.0	0.0	+9.5	+7.6	+1.6	+3.6	−9.8	−1.9	−2.6	−1.5	−7.2	−10.3	−4.1	−1.4	−1.4	+1.9	+2.9	+2.5	+0.9	22	61.0	43.2	104.2	+17.8
	1	178	−27.0	−24.0	Δ	+3.2	+26.0	−3.0	+28.7·	−12.2	+11.8	+29.6·	−54.9·	+2.5	+5.7	+4.8	−25.3	−21.8	−6.6	−2.4	−3.7	+55.4	−5.7	+2.0	−4.4	22	193.7·	167.0·	360.7·	+26.7·
7	T	365	−24.0	+41.1	−26.1	−2.0	−15.1	0.0	−1.9	+4.8	−10.5	−14.7	−12.4·	−0.1	+2.9	+4.1	+14.3	−27.4	−2.1	−3.0	−10.9	+22.3	−6.7	−1.7	+4.8	23	94.3	158.6·	252.9·	−64.3·
	S1	336	+31.4	−39.5	−20.0	+4.0	−13.7	−1.3	−1.4	−4.0	−1.4	+1.0	−26.4	+18.8	+30.4	−2.1	+17.8	+61.7	Δ	Δ	Δ	Δ	+2.2	−2.1	−1.3	19	167.3	113.2	280.5	+54.1
	2	265	−2.5	−1.7	−3.0	−0.8	−6.2	−0.8	−0.5	−4.3	−1.8	−0.2	+5.8	−5.5	−5.3	+3.3	−6.8	Δ	+12.1	+8.0	+9.4	−15.6	+9.5	−5.4	−1.2	22	48.1	61.6	109.7	−13.5
	3	225	−2.4	−1.3	−1.5	−0.2	−7.1	−1.5	−1.0	−4.6	−1.1	−0.6	+0.6	−1.5	−2.1	0.0	+3.0	−15.4	−14.8	−17.1	−10.3	+11.9	+10.9	+5.6	−0.7	23	31.4	83.2	114.6	−51.8
	4	195	−1.6	−2.6	−2.9	−0.1	−5.5	−1.3	−2.0	−5.0	−0.7	−0.3	+0.5	−1.5	−1.4	+0.3	−0.7	+9.2	−2.6	−3.1	−9.1	+3.0	+0.3	−0.2	−1.0	23	13.3	41.6	54.9	−28.3
	5	167	−1.6	−4.4	−1.9	+0.1	−6.9	−0.5	−0.9	−4.2	−0.7	−0.6	+0.1	−2.0	−0.2	−1.5	−1.8	+0.8	+4.1	+6.1	+3.7	−8.4	−0.8	−0.7	−0.5	23	14.9	37.6	52.5	−22.7
	N4	0	0.0	+0.1	+0.4	+0.1	+0.5	+0.8	−0.1	+1.6	−0.5	−0.7	+0.5	−0.7	+0.2	+0.2	−0.1	−0.5	+0.6	+1.4	+0.4	+1.2	+0.8	+1.6	+0.9	23	11.3	2.6	13.9	+8.7
	3	45	−0.8	0.0	+6.3	−2.9	+32.6	+5.0	+8.5	+16.4	+6.2	+4.5	−6.6	−3.9	+13.0	+11.3	−7.4	−6.1	−3.7	+1.3	−0.9	+11.2	−7.2	+2.5	+4.4	23	123.2	39.5	162.7	+83.7
	2	164	−7.0	+20.0	+24.0	Δ	+36.3	−2.2	+12.9	−10.5	+6.5	−0.2	−15.8	+7.2	−0.1	−3.2	−7.2	−10.7	−6.4	0.0	−5.2	+27.8	+6.6	+1.8	−2.1	22	143.1	70.6	213.7	+72.5
	1	237	−7.6	+12.1	+6.4	−1.7	−3.2	−2.0	−0.8	−2.6	+0.1	−2.1	+0.3	−2.2	−3.9	−3.3	+2.4	+3.2	−0.9	−1.0	−3.4	+4.9	−0.9	+0.6	−0.7	23	30.0	36.3	66.3	−6.3
8	T	285	−2.2	−4.6	−6.0	−0.9	−8.9	−0.8	−3.0	−1.3	−3.1	−1.2	+1.7	−1.5	−1.5	−2.6	+0.7	+6.8	+9.2	−0.6	+0.1	−14.7	−0.9	−2.0	+0.1	23	18.6	55.8	74.4	−37.2
	S1	258	+3.3	−0.8	−10.0	−0.4	−7.5	+0.3	−2.3	−3.1	−2.5	−0.1	+2.0	−0.3	−0.1	−1.7	+0.9	+0.7	+3.8	+1.9	+5.3	−17.2	−0.5	−1.6	−0.5	23	18.2	48.6	66.8	−30.4
	2	220	+1.4	−5.0	−7.6	0.0	−8.6	+1.8	−2.0	−0.2	−2.9	+0.2	+2.4	−0.7	−0.9	−2.1	−0.8	Δ	−1.5	−1.2	+1.0	+1.9	+1.4	−0.3	−1.3	22	10.1	35.1	45.2	−25.0
	3	185	+0.2	−3.7	−7.8	+0.3	−8.8	+1.3	−0.8	−1.2	−1.6	+1.9	+3.2	+0.8	−1.2	−2.6	−0.7	−2.4	−0.7	−2.4	+1.2	−5.4	+3.5	−0.7	−0.8	23	12.4	40.8	53.2	−28.4
	4	146	0.0	−2.8	−3.1	+0.2	−3.3	+0.4	−0.9	−2.0	+0.5	+1.0	+2.0	−3.3	+1.2	−1.1	−0.1	−2.7	+0.4	Δ	Δ	−0.9	+5.2	−0.4	−1.3	21	10.9	21.9	32.8	−11.0
	5	120	−0.7	+1.0	+1.2	−0.5	0.0	0.0	+1.1	+1.5	+1.0	−1.4	−2.2	+3.5	−2.5	−2.5	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	14	9.3	9.8	19.1	−0.5

H.G. : Height of Ground-surface N.M. : Number of Measuring A : Accumulation E : Erosion Δ : Unmeasured • : Uncertain value

Table 8. Additional change length of each measured pile on the natural sand dune

(Dec., 1986 – Aug., 1987)

(cm)

Direction / Measurement point	North side 5	4	3	2	1	Top of dune	South side 1	2	3	4	5	6
Line No. 1	–	107.0	133.6	231.0	211.9	254.1	135.1	30.7	53.4	58.2	–	–
No. 2	–	11.9	20.3	139.8	292.4	264.9	162.3	60.3	37.6	64.2	–	–
No. 3	–	13.2	26.3	77.9	255.1	338.0	199.4	119.0	50.4	36.2	–	–
No. 4	–	26.0	48.0	157.8	368.3	271.4	156.6	54.7	44.8	55.0	41.6	25.9
No. 5	13.4	102.1	137.6	225.1	215.9	269.5	229.2	54.0	48.6	34.5	15.6	–
No. 6	–	31.9	44.8	120.6	321.2	308.2	222.4	181.9	30.5	193.8	–	–
No. 7	–	16.1	27.8	104.2	360.7	252.9	280.5	109.7	114.6	54.9	52.5	–
No. 8	–	13.9	162.7	213.7	66.3	74.4	66.8	45.2	53.2	32.8	19.1	–
Mean value	88.3					232.4	61.1					

+ Uncertain value

Table 9. Captured amounts of blowing sand in different heights from ground surface of the natural sand dune

Site	Heights of ground surface (m)	(1987) Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Total (%)
Top of sand dune	0.2	134.8	4099.7	12948.1	28932.7	16426.3	364.0	2063.8	64969.4 (91.4)
	0.5	0.6	556.0	854.6	1939.6	916.0	522.3	1304.1	6093.2 (8.6)
	1.5	0.1	△	△	△	△	△		0.1 (0.0)
	Total	135.5	4655.7	13802.7	30872.3	17342.3	886.3	3367.9	71062.7 (100.0)
Base of north side	0.2	0.6	1416.5	3629.1	576.7	1476.7	471.3	450.3	18021.2 (83.1)
	0.5	0.5	422.7	920.7	129.4	43.7	47.8	70.9	1635.7 (16.9)
	1.5	0.1	△	△	△	△	△		0.1 (0.0)
	Total	1.2	1839.2	4549.8	1706.1	1520.4	519.1	521.2	9657.0 (100.0)

+ Uncertain value △ Unmeasured

(3) Effects of Date-fronds-mat-fence on Erosion Control, Microclimiate and Tree Growth

ABSTRACT

This experiment was conducted to investigate the effects of different densities of date-fronds-mat-fence on erosion control, microclimate and growth of planted trees.

The study was carried out on the west side of the Agr. Exp. Sta. of U.A.E. University at Al-Oha. It was located on a flat area in sandy soil. Treatments were three densities of fence (10 x 10 m, 20 x 20 m and 30 x 30 m) and a control without fence. Seventy two seedlings of each Samar (*Acacia tortilis*) and Ghaff (*Prosopis spicigera*), typical species for erosion control in the United Arab Emirates, were planted in each plot. They were one year old at the time of planting. Each experimental plot was 60 x 60 m.

Soil physical properties, soil infiltration rate and the amount of shifting sand were studied in each plot prior to the study and plots were found to be highly homogenous in these aspects.

Clear differences were recognized on the amount of shifting sand at 20 cm high from the ground surface inside each plot. The preventive efficiency of shifting sand due to treatments of D-30 (30 x 30 m), D-20 (20 x 20 m) and D-10 (10 x 10 m) was respectively 72.7%, 91.3% and 99.1% as compared with the control plot (D-0). Values were monthly means for the period from April 1 to August 31, 1987.

Ground surface was stabilized and vegetation increased in treated plots as compared with the control plot. The relative values of tree height of Ghaff were 139, 126 and 121 for D-10, D-20 and D-30, respectively, as compared with 100 for the control (D-0).

Total cost of fence construction was calculated for each plot. Cost was highest in the D-10 plot which showed the highest preventive efficiency of shifting sand.

INTRODUCTION

Date-fronds-mat-fence is effective in protecting trees from wind erosion. Newly-planted trees are usually exposed to severe conditions of wind erosion and soil moisture shortage in arid land.

It is believed that date-fronds-mat-fence can stabilize the environment by reducing wind velocity, preventing shifting sand and limiting evaporation especially inside the fenced area. Therefore, newly trees will be protected and continue to grow normally. One disadvantage of the date-fronds-mat-fence is that it is a short-term method of the control of shifting sand for the civil engineering stand point. This experiment investigates the effect of different densities of date-fronds-mat-fence on environment, microclimate, and growth of newly standing trees.

MATERIALS AND METHODS

Layout of the Experiment

The experiment was set up on the west side of the experimental farm of U.A.E. University at Al-Oha (20 km north from Al-Ain, 180 km west from Abu Dhabi). Three densities of date-fronds-mat-fence were established in different 60 x 60 m plots. All plots were surrounded with the fence. The control plot (D-0) was left without further fencing. Treated plots were divided further into 10 x 10 m (D-10), 20 x 20 m (D-20), or 30 x 30 m (D-30) squares by fencing within each plot. Their layout is shown in Fig. 1.

The mat-fence was made of date (Phoenix spp.)-fronds with woody stakes and bar at one meter high from the ground surface as shown in Fig. 2.

Seventy two seedlings of one year-old seedling of each Samar (*Acacia tortilis*) and Ghaff (*Prosopis spicigera*) were planted in each plot as shown in Fig. 3 and 4. Treatment, applied, used and the time schedule of the experiment are shown in Table 1, 2 and 3.

Measurement of Initial Conditions

Soil infiltration was measured in the environmental plots prior to the start of the experiment using a cylinder type infiltrometer. 10 cm in diameter and 20 cm in height (Fig. 6). Water infiltration rate in mm/hour was also calculated.

Undisturbed soil samples were analyzed for soil physical properties. Samples were taken at a depth of 1 to 5 cm using a sampling cylinder which has a volume of 100 cc. Total porosity, soil moisture content, water holding capacity, minimum air space and coefficient of perolation were measured.

Shifting and blowing sand were captured with swivel catching device designed by K. Suzuki at a height of 20 cm, 50 cm, 100 cm and 150 cm from the ground surface (Fig. 8). Degices were installed at the center of D–0 (control) plot. Shifting and blowing sand were collected and weighed every 10 days beginning from December 1986 to August 1987.

Measurement of Microclimate

Prevention of shifting sand, stabilization of ground surface and soil moisture were investigated in order to study the effects of the fence on microclimate. Preventive efficiency of shifting sand was estimated by the amount of shifting sand captured with swivel catching devices. They were set up and arranged diagonally at a height of 20 cm from the ground in each plot as shown in Fig. 9. Shifting sand captured with divices was collected once every 10 days beginning from April 1987.

The amount of natural vegetation was measured in order to realize the extent of stabilization of ground surface in each plot. Pioneer vegetation was observed for approximately 5 months after the construction of sand fence from December 1986 to May 1987 (Table 4).

Samples for soil moisture were taken at the base of planted trees at a depth of 0 – 1 cm, 1 – 10cm, 10 – 30 cm, 30 – 50cm, 50 – 70 cm and 70 – 100 cm from the ground surface on May, August and December 1987. Soil samples were dried at 105°C for 10 hours and then weighed.

Measurement of Tree Growth

The following parameters were measured to study plant growth starting from April 1987: tree height from the ground surface, diameter of main trunk at 10 cm from the ground surface, and crown diameter. Tree height was measured to the tallest shoot. Diameter of main trunk was measured with a vernier caliper.

Ghaff and Samar exhibited morphologically different features in their shape. In case of Ghaff, the crown was coniform. And it is certain to measure each part of trees because of clear main trunk and shoot. On the contrary, there are many trunks growing from the base of trees in case of Samar. In addition, each trunk expand horizontal branches forming an umbrella shape. Therefore, a diameter of the biggest trunk was measured as the diameter of the trees.

The longest (L) and the shortest crown (S) of trees can be approximate a circle. As a result, mean crown diameter (C) was calculated as below.

$$C = (L + S)/2$$

Furthercmore, crown area (CA) in each tree and covering ratio (CR) in each plot were calculated by the following equation.

$$CA = 3.14 \times r^2 \qquad r = c/2$$

$$CR = \sum_{n=1}^{n} (CA)/TP \times 100\ (\%)$$

n : Number of measured trees

TP : Area of treatment plot (3600 m^2)

RESULTS AND DISCUSSION

Initial Conditions of the Experimental Plots

Soil infiltration rate

Table 5 shows result obtained by the infiltration rate in each plot. The initial, final and mean infiltration rates were, respectively, 2231.8, 532.1, and 747.1 mm/hr in plot D-0, 2292.9, 764.5, and 925.2 mm/hr in plot D-30, 1914.2, 596.3, and 752.1 mm/hr in plot D-20, and 1971.9, 400.5, and 552.4 mm/hr in plot D-10. The infiltration rate was of the same magnitude in various plots though it was highest in plot D-30 and lowest in plot D-10.

Soil physical properties and soil three phases distribution in each plot

Result obtained on soil physical properties are shown in tables 6 and 7. The order of magnitude of saturated permeability in each plot was 10–3 cm/sec. The order is approximately equal to the known order of sandy soil. Other soil physical properties such as bulk density, total porosity, water holding capacity, minimum air space and soil moisture contents also showed values comparable to known values of sandy soil.

Soil three phases distribution was almost similar in each plot. The proportion of solid, liquid and air phases were in the range of 66.5 – 66.7, 1.8 – 2.7, 29.6 – 31.6%, respectively.

Amount of shifting and blowing sand captured at different heights from ground sruface

Amount of shifting and blowing sand captured at different height from ground surface at the center of the control plot D-0 is shown in Table 8. Monthly amount of captured sand was highest in March (2740.72 g/cm^2) and lowest in December (2.52 g/cm^2). The amount in March was about 1000 times as in December. The amount of captured sand at 20 cm height from ground was more than total amount of the other heights, this amount reached approximately 90% of all.

Distribution of the monthly amount of shifting and blowing sand at different heights from the ground surface is shown in Fig. 10 and 11. The relationship between the amount of captured sand and height from the ground surface is nearly linear or curved under the logarithm functions although it would be necessary to collect more data.

Effects of sand fence on microclimate

Prevention of shifting sand: Data obtained on the monthly amount of shifting sand preventive efficiency of treatments as compared with the control plot (D-0) at 20 cm height from the ground are presented in Table 9 and Fig. 12. Higher density of the fence exhibited higher efficiency. Preventive efficiency of plots D-30, D-20 and D-10 were, respectively, 72.7%, 91.3% and 99.1% from April to August. The fences of plots D-20 and D-10 prevented shifting sand 90% more than in the control plot (D-0).

Stabilization of ground surface: Total amount of pioneer vegetation in D-10, D-20, D-30 and D-0 was 7511.35 g, 5501.08 g, 5215.50 g and 4911.02 g, respectively. Higher density of dates-fronds-mat-fence maintained more pioneer vegetation during the observation period from December 1986 to May 1987. *Cyperus conglomeratus* was the most dominant in the control plot (D-0). Large amount of *Eremobium aegyptiacum* appeared in all plots. *Tribulus longipetaus* tended to increase in the more stable conditions. *Hamada elegans* and *Euphorbia granulata* didn't appear in the control plot but increased in plots with higher fence density.

Soil moisture: Data obtained on the distribution of soil moisture at different depths from the ground surface are shown in Fig. 14. Soil moisture in plot D-10, which had the highest fence density was always higher than in other plots. Soil moisture of other plots showed 1 – 2% in the surface and 4 – 6% at a depth of 70 –100 cm. Values increased gradually from the surface to a depth of 10 or 30 cm, but was generally constant at 30 – 100 cm.

Effects of sand fence on tree growth

Tree height: Results obtained on tree height are shown in tables 11 and 12 and Fig. 15 and 16. Samar (*Acacia tortilis*) showed good growth in April and but its growth declined in June. Mean tree height was highest in plot D-20 and lowest in plot D-0. According to the t-test (0.05), no significant differences were found in tree height between plots except between plot D-0 and D-20 in April, and between plot D-0 and D-10, D-0 and D-20, D-20 and D-30 in August. Consequently, no clear effects of dates fronds mat fence on Samar height were recognized.

Ghaff (*Prosopis spicigera*), on the contray, grew well from April to August. Planted trees enclosed by higher density of date-fronds-mat-fence showed better in height. According to t-test, there was no significance differences between plots except between plots D-20 and D-30 in August. A clear effect of sand fence was recognized between non-treated plot and treated plots.

Diameter: Tree diameter at 10 cm high from the ground surface is shown in Tables 15 and 16 and Fig. 17 and 18. Samar showed slight increase in diameter from April to August. Accordingly, the clear effect of sand fence was not evident although there was a significant differences among plots except between D-10 and D-20 plot in August.

Ghaff showed good growth from April to August, and there was a significance among each plot in August.

Crown diameter: Samar and Ghaff showed the same tendency in crown diameter. Both trees showed longer crown diameter when surrounded by higher density of sand fence.

Covering area: Covering area is one of the most important factors for erosion control. Trees can be more effective collectively, but they are not effective individually for erosion control. Calculations of the covering area and covering ratio are shown in Tables 23 and 24 and Fig. 21 and 22. Covering area of Ghaff was always larger than that of Samar in each plot, being three or four times larger in August. Total covering area in each plot was respectively 35 m^2 in plot D-0, 124 m^2 in plot D-10, 82 m^2 in plot D-20 and 70 m^2 in plot D-30 in August. Trees in plots with higher density of sand fence tended to be larger than those in plots with lower density of sand fence.

Percentage dead trees: Percentage dead trees is shown in Table 25. Tree death was higher in plot D-30 than in all other plots in April, being 2.78%, tree death was highest in plot D-20 from May to August, being 4.17%.

Cost benefit of date-fronds-mat-fence

Date-fronds-mat-fence was effective in control for wind erosion. It was recognized that the higher density of this fence was more effective in the preliminary growth of trees and in controlling the environment of the surrounded area. We calculated the cost benefit of these fences, and we studied the effect of these fences on tree growth, and microclimate. Results are shown these fences on tree growth, and microclimate. Results are shown in Table 26 and Fig. 23 and 24. The relationship between preventive efficiency of shifting sand and the cost for the construction of date-fronds-mat-fence could be approximate with exponent function as shown in Fig. 23. Namely, more cost made more effect in preventing shifting sand, but its maximum density of sand fence was approximately 100 m^2 (D-10 plot). Therefore, even if we would spend more than that of D-10 plot we couldn't obtain more effect in preventing shifting sand. On the other hand, more cost for the construction of the fence showed better result in mean tree height growth in Ghaff from April to August shown in Fig. 24.

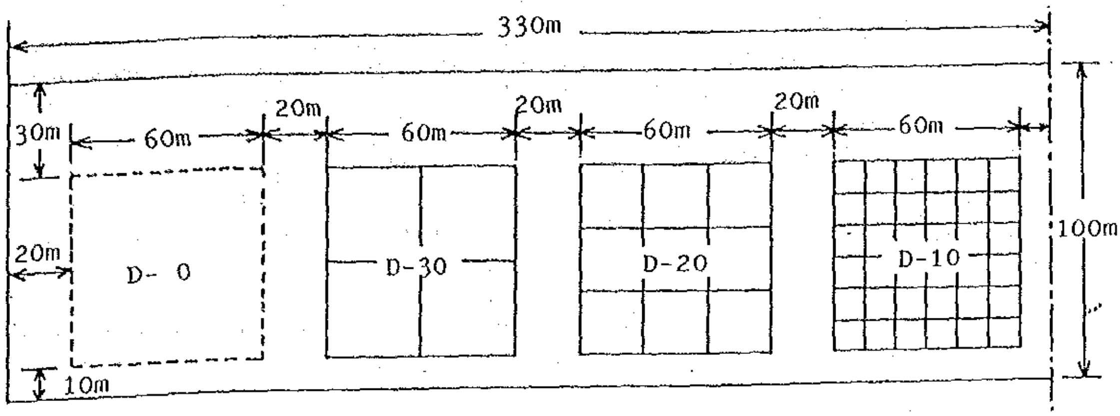


Fig. 1 Arrangement of the experimental plots

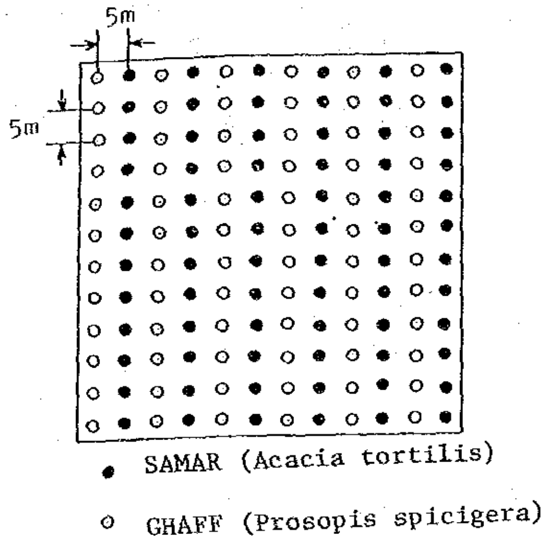


Fig. 2 Arrangement of tree planting

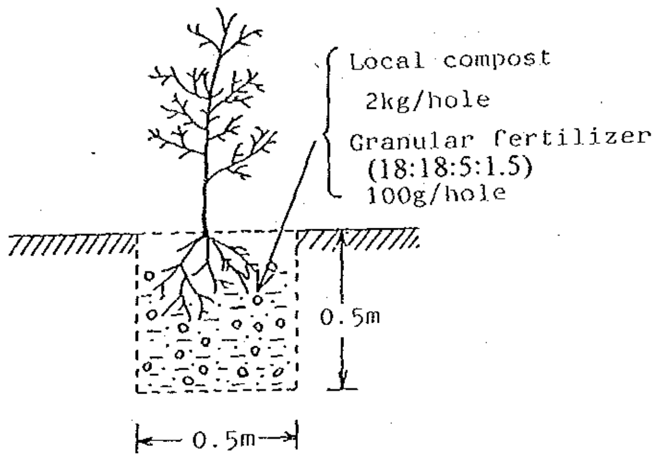


Fig. 3 Practice of tree planting

Table 1 Experimental treatment

Plot name	Materials of sand fence	Density	Height	Species	Number
D - 30	Dates fronds mat	30mx30m	1 m	Samar Ghaff	72 72
D - 20	"	20mx20m	"	"	"
D - 10	"	10mx10m	"	"	"
D - 0	-	-	-	"	"

* Irrigation level : 20 litter/tree/day

Table 2 Materials for the experimental treatment

Materials	Unit	D - 10	D - 20	D - 30	D - 0
1. Dates Fronds Mat (2.4mx2.4m)	Roll	175	113	75	0
2. Woody Stay (2x4inchx2m)	Piece	420	270	180	0
3. Woody Bar (2x2inchx4m)	Piece	840	540	360	0
4. Wire and Nail					
5. Steel Bamboo	Piece	144	144	144	144
6. One year old SAMAR (Acacia tortilus)	Piece	72	72	72	72
7. One year old GHAFF (Prosopis spicigera)	Piece	72	72	72	72
8. Fertilizer (Granular)	kg	14.4	14.4	14.4	14.4
9. Fertilizer (Local compost)	kg	288	288	288	288
10. Labour	man.day				

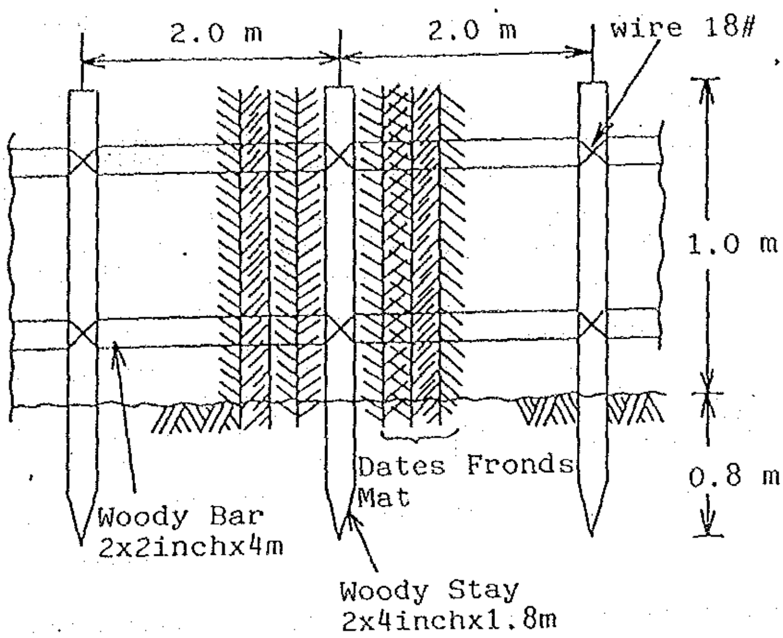


Fig. 4 Structure of sand fence made of dates fronds mat

Table 3 The progress of the experiment

Item	Date	Contents
1. Leveling of the Experimental Area	October 1985 ~ November 1985	Bulldozer
2. Construction of Sand Fence	December 24, 1986 ~ February 8, 1987	Dates fronds mat made of phoenix sp.
3. Tree Planting	April 9, 1987 ~ April 16, 1987	Samar 72x4 Plots Ghaff 72x4 Plots
4. Irrigation	April 9, 1987 ~ April 27, 1987	Everyday 30 Litter/Tree EC = 0.9 mS
	April 28, 1987 ~ May 15, 1987	Everyday 20 Litter/Tree EC = 0.9 mS
	May 16, 1987 ~ July 16, 1987	Everyday 20 Litter/Tree EC = 4-7 mS
	July 17, 1987	Everyday 20 Litter/Tree EC = 8-9 mS

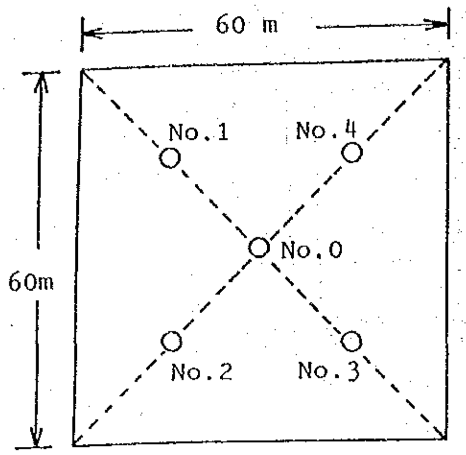


Fig. 5 Measurement and sampling point of soil

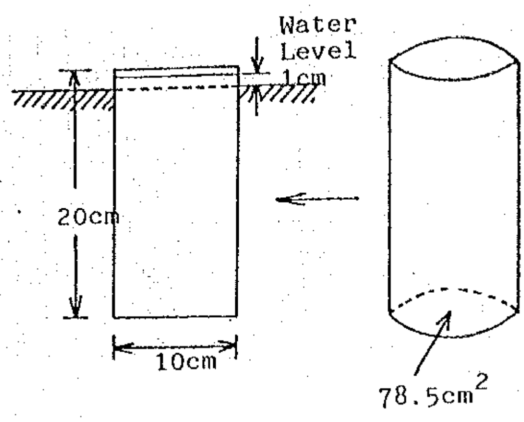


Fig. 6 Cylinder type infiltrometer and setting in the soil

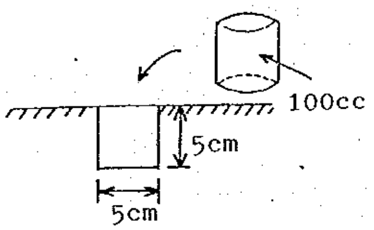


Fig. 7 Depth of soil sampling and sampling cylinder of 100 cc

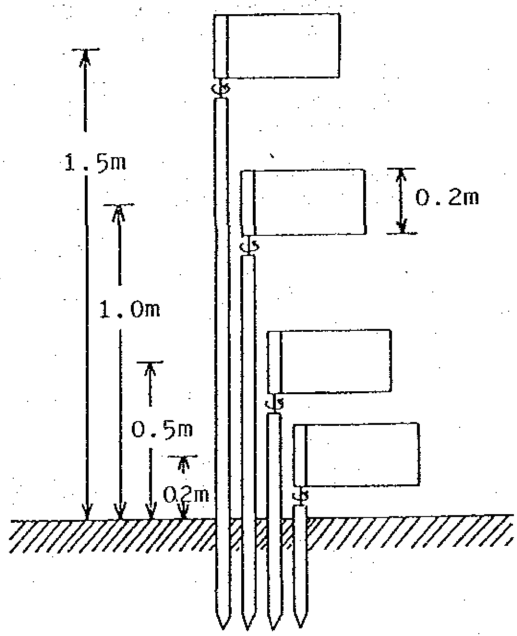


Fig. 8 Swivel catching device for shifting and blowing sand

Table 4 Process of investigation on pioneer vegetation

Contents	D - 10	D - 20	D - 30	D - 0
1. Leveling of Area	October 1985 - November 1985			
2. Construction of Fence	December 24,1986 - February 8,1986			
3. Tree Planting	April 9,1987 - April 16,1987			
4. Irrigation Start	April 9,1987			
5. Date of Investigation	May 3-4 1987	May 9 1987	May 5 1987	May 7 1987
6. Period of Observation	December 1986 - May 1987			

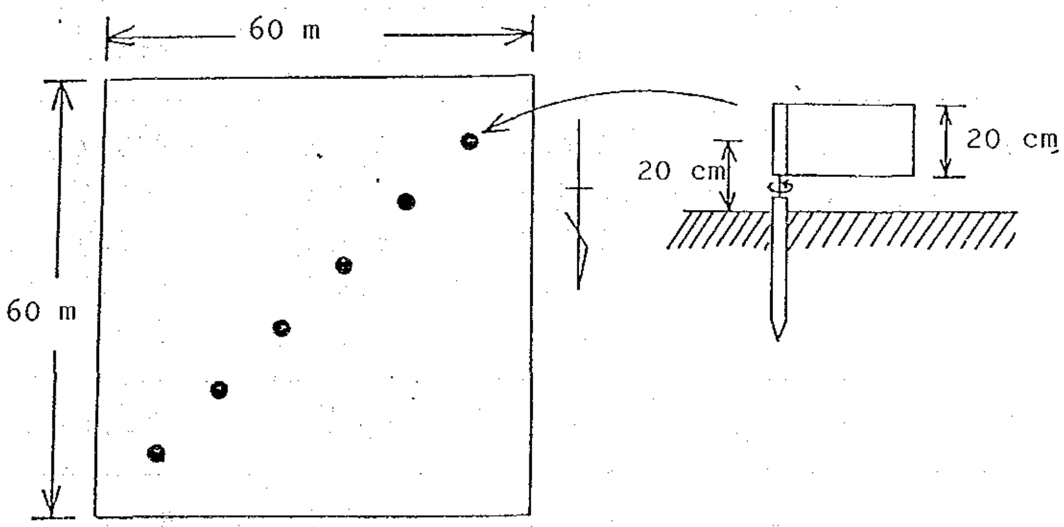


Fig. 9 Swivel catching device and arrangement in each plot

Table 5. Infiltration capacity in each plot

Plot	Measurement Point No.	Infiltration rate (mm/hr) Initial	Final	Mean
D - 0	0	2216.5	458.7	723.6
	1	2216.5	535.2	703.2
	2	1452.2	382.3	560.6
	3	2675.1	626.9	800.0
	4	2598.6	657.5	947.9
	Average	2231.8	532.1	747.1
D - 30	0	2216.5	535.2	800.0
	1	2445.8	856.2	1024.3
	2	2675.1	749.2	1003.9
	3	2140.0	917.4	947.9
	4	1987.2	764.5	851.0
	Average	2292.9	764.5	925.2
D - 20	0	2216.5	657.5	835.7
	1	2063.6	718.6	851.0
	2	1087.2	519.7	677.8
	3	1987.2	382.3	565.6
	4	2216.5	703.2	830.6
	Average	1914.2	596.3	752.1
D - 10	0	2063.6	321.1	438.3
	1	1987.2	382.3	484.1
	2	1987.2	351.2	570.8
	3	1757.9	290.5	504.5
	4	2063.6	657.5	764.4
	Average	1971.9	400.5	552.4

Table 6. Soil physical properties in each plot

Plot	Measurement Point No.	Depth (cm)	Saturated permeability (cm/sec)	Bulk Density (g/cm^3)	Total Porosity (%)	Water Max. Weight (%)	Water Max. Volume (%)	Air Min. (%)	Moisture Contents of Fresh Soil Weight (%)	Moisture Contents of Fresh Soil Volume (%)
D- 0	No. 0	0 - 5	5.46×10^{-3}	1.74	35	21	37	- 2	0.9	1.6
	1	"	6.49×10^{-3}	1.77	34	20	36	- 2	1.0	1.7
	2	"	7.98×10^{-3}	1.76	34	21	36	- 2	0.9	1.6
	3	"	6.91×10^{-3}	1.79	33	20	36	- 3	1.3	2.3
	4	"	6.91×10^{-3}	1.83	32	20	36	- 4	1.3	2.3
	Average	0 - 5	6.75×10^{-3}	1.78	34	20	36	- 3	1.1	1.9
D-30	No. 0	0 - 5	7.98×10^{-3}	1.82	34	15	27	7	1.5	2.7
	1	"	6.49×10^{-3}	1.80	33	11	21	12	1.6	2.8
	2	"	-	-	-	-	-	-	-	-
	3	"	10.0×10^{-3}	1.80	32	20	36	- 4	1.4	2.5
	4	"	7.98×10^{-3}	1.85	31	19	36	- 5	1.4	2.6
	Average	0 - 5	8.11×10^{3}	1.82	33	16	30	3	1.5	2.7
D-20	No. 0	0 - 5	9.43×10^{-3}	1.81	32	20	36	- 4	1.2	2.1
	1	"	9.43×10^{-3}	1.72	35	21	35	0	0.9	1.6
	2	"	7.98×10^{-3}	1.77	33	20	36	- 3	1.0	1.8
	3	"	9.43×10^{-3}	1.77	33	21	36	- 3	0.9	1.7
	4	"	9.43×10^{-3}	1.80	33	20	36	- 3	1.1	2.0
	Average	0 - 5	9.14×10^{-3}	1.77	33	20	36	- 3	1.0	1.8
D-10	No. 0	0 - 5	-	1.80	32	20	36	- 4	1.5	2.6
	1	"	7.41×10^{-3}	1.76	35	20	36	- 1	1.2	2.1
	2	"	6.91×10^{-3}	1.71	33	21	36	- 3	1.1	1.9
	3	"	6.91×10^{-3}	1.76	33	21	36	- 3	0.9	1.7
	4	"	6.91×10^{-3}	1.79	33	21	37	- 4	0.8	1.5
	Average	0 - 5	7.04×10^{-3}	1.76	33	21	36	- 3	1.1	2.0

Table 7. Three phase distribution in each plot

Plot	Measurement Point No.	Depth (cm)	Solid Phase (%)	Liquid Phase (%)	Air Phase (%)
D- 0	No. 0	0 - 5	65.4	1.6	33.0
	1	"	65.9	1.7	32.4
	2	"	66.0	1.6	32.4
	3	"	67.0	2.3	30.7
	4	"	68.3	2.3	29.4
	Average	0 - 5	66.5	1.9	31.6
D-30	No. 0	0 - 5	66.4	2.7	30.9
	1	"	67.4	2.8	29.8
	2	"	-	-	-
	3	"	67.7	2.5	29.8
	4	"	69.2	2.6	28.2
	Average	0 - 5	67.7	2.7	29.6
D-20	No. 0	0 - 5	68.0	2.1	29.9
	1	"	64.8	1.6	33.6
	2	"	66.9	1.8	31.3
	3	"	67.2	1.7	31.1
	4	"	67.0	2.0	31.0
	Average	0 - 5	66.8	1.8	31.4
D-10	No. 0	0 - 5	67.7	2.6	29.7
	1	"	65.5	2.1	32.4
	2	"	66.9	1.9	31.2
	3	"	66.8	1.7	31.5
	4	"	67.0	1.5	31.5
	Average	0 - 5	66.8	2.0	31.2

Table 8. Monthly amount of shifting sand captured with swivel catching device in the different height from the ground

Height from the Ground	Dec. 1986	Jan. 1987	Feb.	Mar.	Apr.	May	June	July	Aug. (20days)	Total
20 cm	2.11	3.13	292.84	2475.09	176.47	243.10	392.22	159.70	398.34	4143
	83.59	88.55	86.20	90.31	89.71	74.85	96.87	93.57	86.30	89.19
50 cm	0.23	0.19	27.76	192.46	16.37	77.10	8.08	7.95	52.13	382.27
	9.09	5.41	8.17	7.02	8.32	23.74	2.00	4.66	11.29	8.23
100 cm	0.10	0.12	11.79	44.05	2.01	2.41	2.73	2.01	7.90	73.12
	3.91	3.43	3.47	1.61	1.02	0.74	0.67	1.18	1.71	1.57
150 cm	0.09	0.09	7.31	29.11	1.86	2.15	1.86	1.02	3.22	46.71
	3.41	2.61	2.15	1.06	0.95	0.66	0.46	0.60	0.70	1.01
Total	2.52	3.53	339.70	2740.72	196.71	324.76	404.89	170.68	461.59	4645.1
	100.00	100.00	99.99	100.00	100.00	99.99	100.00	100.01	100.00	100.00

unit : upper $g/100cm^2/month$

: lower %

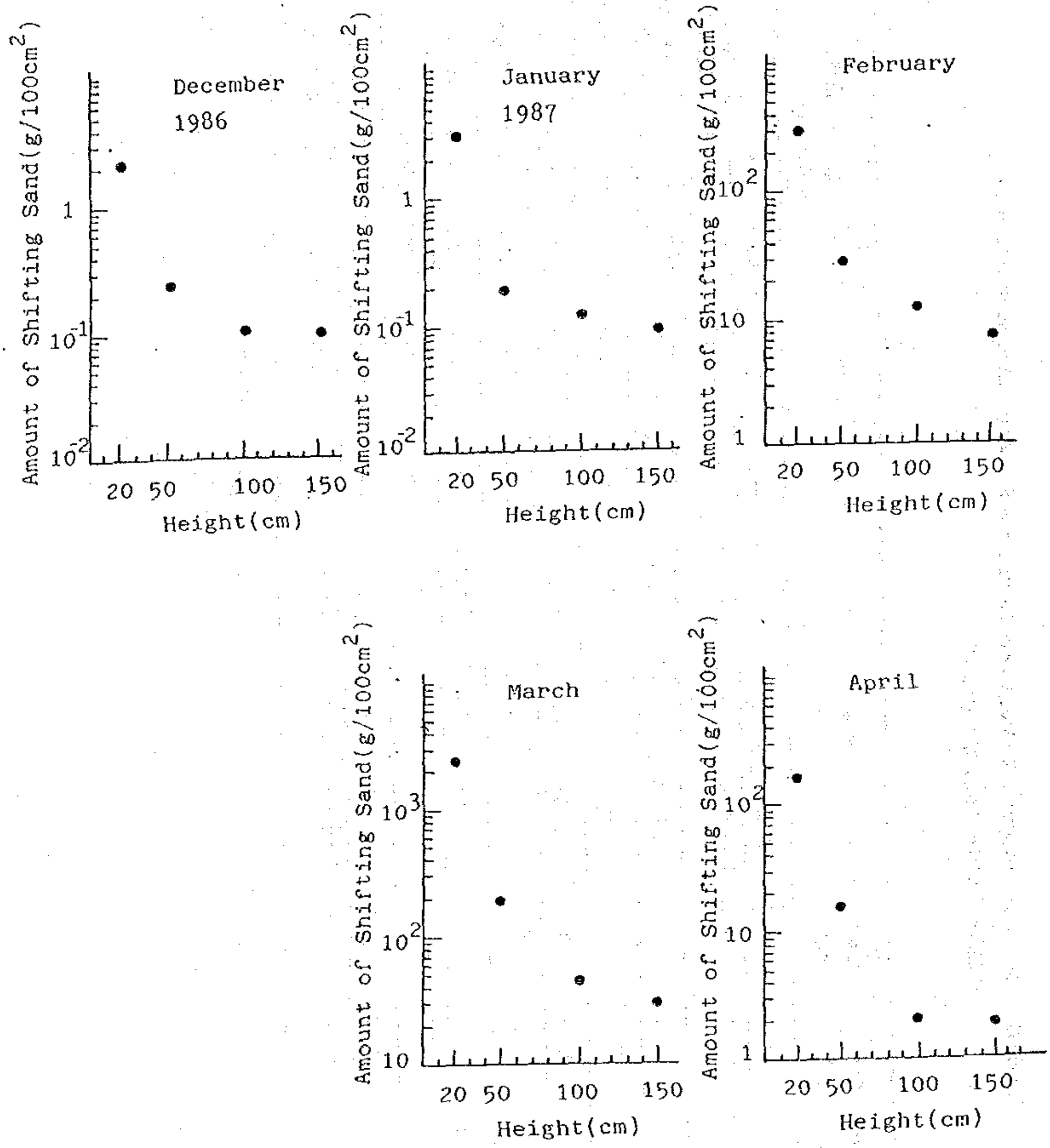


Fig. 10. Distribution of monthly amount of shifting sand captured with swivel catching device in the different height from the ground

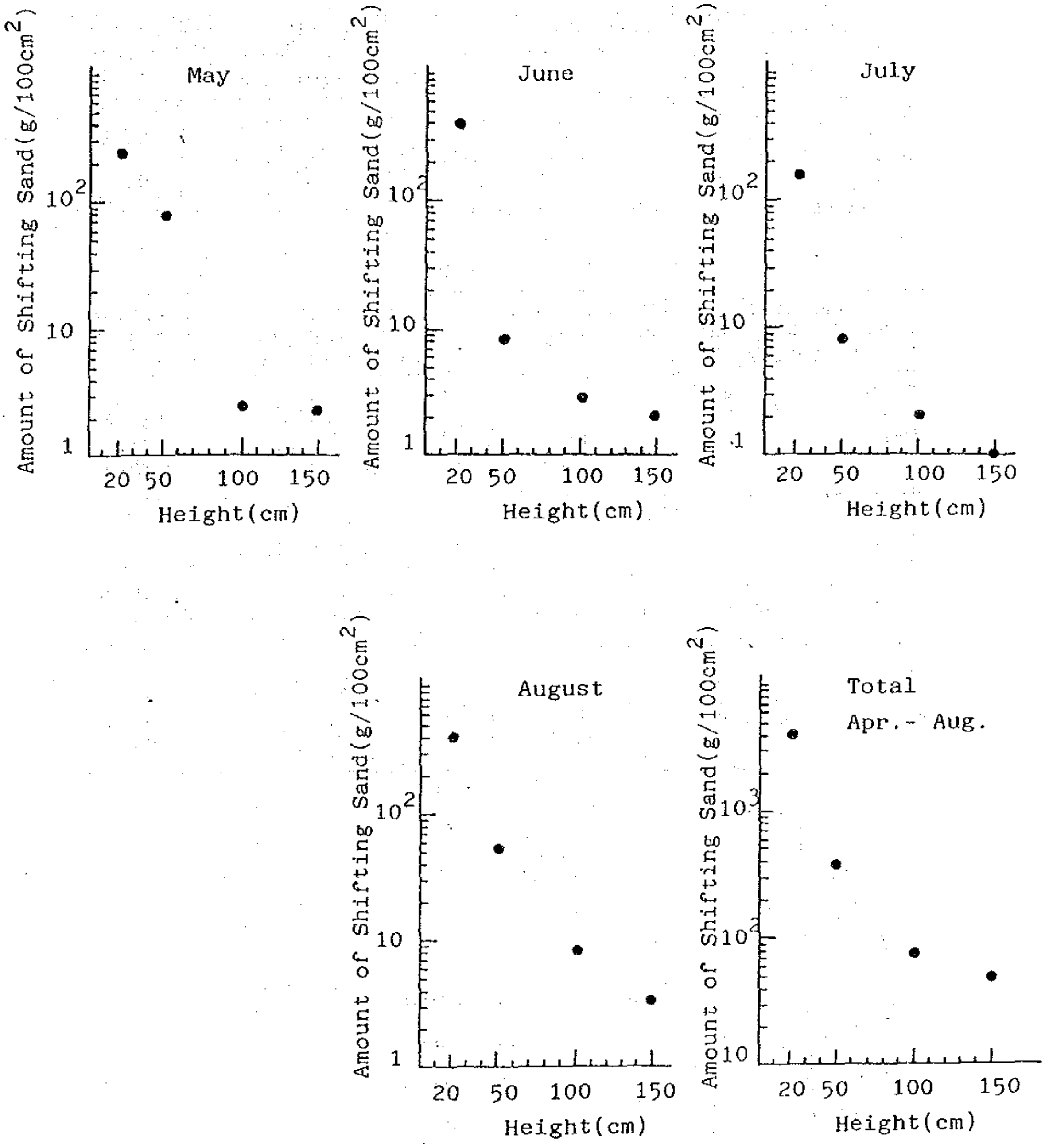


Fig. 11. Distribution of monthly amount of shifting sand captured with swivel catching device in the different height from the ground

Table 9. **Monthly amount of shifting sand and preventive efficiency as compared with D-0 (control) plot at 20 cm high from the ground**

April

Plot	Amount of Shifting Sand ($g/100cm^2/month$)	Preventive Efficiency (%)
D- 0	279.24	-
D-30	46.29	83.5
D-20	15.97	94.3
D-10	1.52	99.3

May

Plot	Amount of Shifting Sand ($g/100cm^2/month$)	Preventive Efficiency (%)
D- 0	297.99	-
D-30	121.33	59.4
D-20	38.02	87.2
D-10	3.22	99.0

June

Plot	Amount of Shifting Sand ($g/100cm^2/month$)	Preventive Efficiency (%)
D- 0	383.53	-
D-30	88.23	77.1
D-20	27.83	92.7
D-10	4.11	99.0

July

Plot	Amount of Shifting Sand ($g/100cm^2/month$)	Preventive Efficiency (%)
D- 0	260.52	-
D-30	92.20	64.8
D-20	34.09	87.0
D-10	3.44	98.9

August

Plot	Amount of Shifting Sand ($g/100cm^2/month$)	Preventive Efficiency (%)
D- 0	2913.62	-
D-30	625.47	78.6
D-20	133.70	95.4
D-10	23.31	99.2

April to August in 1987

Plot	Amount of Shifting Sand ($g/100cm^2/month$)	Preventive Efficiency (%)
D- 0	4134.90	-
D-30	973.52	72.7
D-20	249.60	91.3
D-10	35.61	99.1

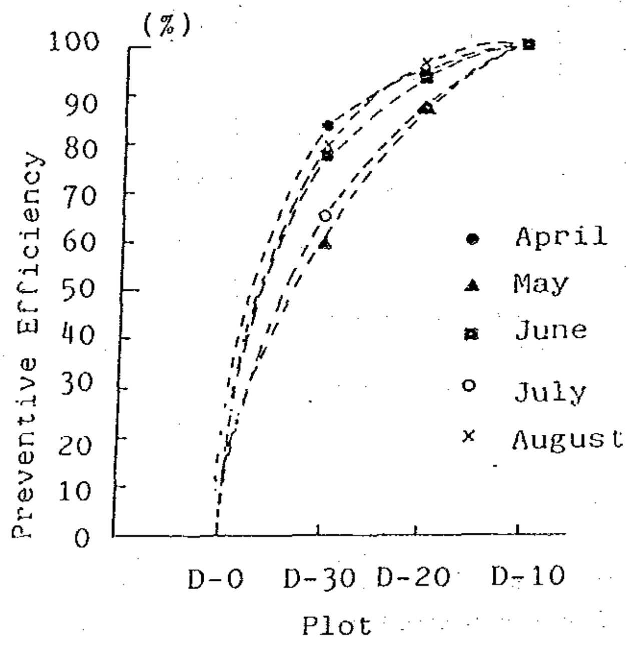


Fig. 12. **Preventive efficiency as compared with D-0 (control) plot in the height of 20 cm from the ground**

Table 10. Development of Natural Vegetation for four months in each plot

Species	D - 10	D - 20	D - 30	D - 0	Total
Cyperus conglomeratus	287.22 / 3.82	1265.13 / 23.00	943.60 / 18.09	4088.2 / 83.25	6584.15 / 28.45
Tribulus longipetals	1327.51 / 17.67	468.97 / 8.53	739.10 / 14.17	31.21 / 0.64	2566.79 / 11.09
Eremobium aegyptiacum	2025.04 / 26.96	2721.22 / 49.47	3198.85 / 61.33	789.92 / 16.08	8735.03 / 37.75
Euphorbia granulata	3007.37 / 40.04	888.30 / 16.15	310.25 / 5.95	0 / 0	4205.92 / 18.18
Haloxylon salicornicum	743.02 / 9.89	54.55 / 0.99	10.28 / 0.20	0 / 0	807.85 / 3.49
Others	121.19 / 1.61	102.91 / 1.87	13.42 / 0.26	1.69 / 0.03	239.21 / 1.03
Total	7511.35 / 99.99	5501.08 / 100.01	5215.50 / 100.00	4911.02 / 100.00	23138.95 / 99.99

unit : upper; Fresh Weight(g)
: lower; Weight Percentage(%)

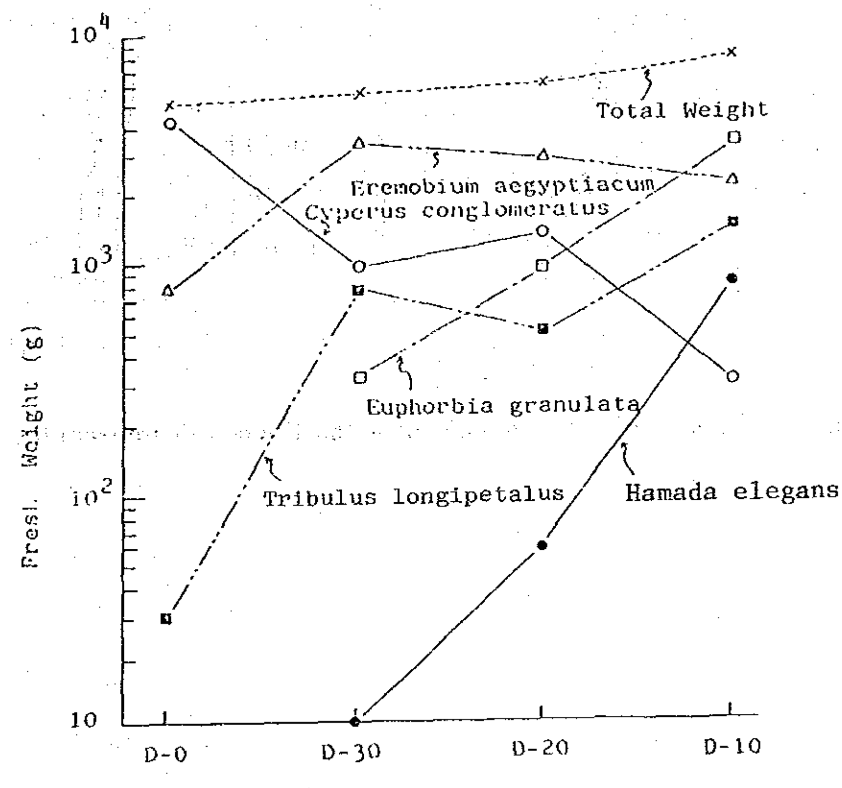


Fig. 13. Development of natural vegetation for four months in each plot (Dec. 1986 – May 1987)

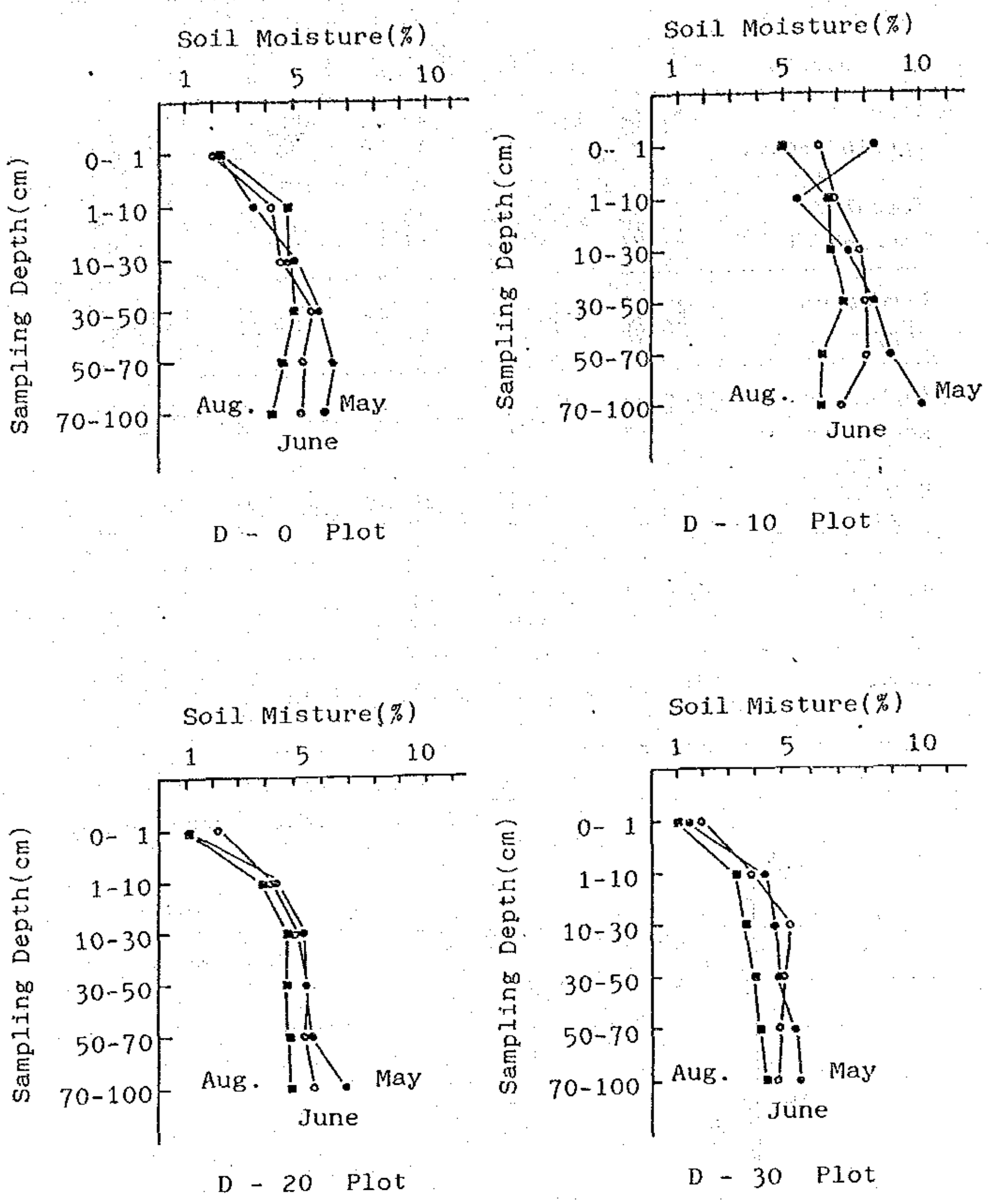


Fig. 14. Distribution of soil moisture in the different depth from the surface

Table 11. Result of the measurement for tree height from the ground

Acacia tortilis (Samar)

Month		D - 10	D - 20	D - 30	D - 0
April	Mean (cm)	46.43	50.02	47.50	44.60
	Variance	111.350	134.590	101.676	84.613
	Number	71	70	70	72
May	Mean (cm)	51.93	55.58	51.80	49.42
	Variance	144.925	200.247	122.575	133.716
	Number	72	72	72	70
June	Mean (cm)	56.60	61.34	54.84	55.28
	Variance	185.183	260.329	160.698	181.256
	Number	72	72	72	69
July	Mean (cm)	57.69	61.26	55.08	55.24
	Variance	188.195	282.545	172.289	188.367
	Number	72	71	72	69
August	Mean (cm)	59.85	62.83	55.90	55.21
	Variance	199.038	295.845	164.041	183.745
	Number	71	71	72	69

Table 12. Result of the measurement for tree height from the ground

Prosopis spicigera (Charr)

Month		D - 10	D - 20	D - 30	D - 0
April	Mean (cm)	45.64	45.83	46.03	45.95
	Variance	89.837	91.283	138.165	155.774
	Number	71	71	70	71
May	Mean (cm)	57.86	57.72	56.12	52.27
	Variance	138.759	171.866	195.318	218.413
	Number	72	69	72	71
June	Mean (cm)	72.64	73.13	71.15	62.04
	Variance	211.917	270.294	358.170	255.622
	Number	72	67	72	71
July	Mean (cm)	94.00	89.53	87.35	73.93
	Variance	355.418	404.760	472.690	386.791
	Number	72	67	72	71
August	Mean (cm)	113.45	102.09	98.67	81.34
	Variance	409.175	395.337	619.278	534.780
	Number	72	67	72	71

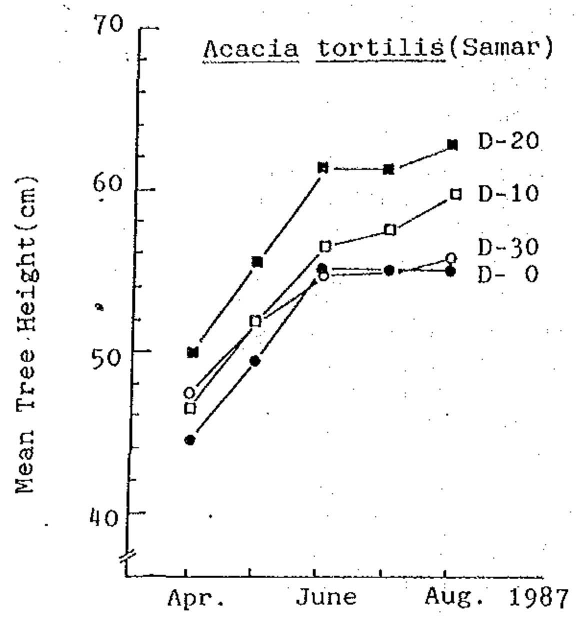


Fig. 15. **Monthly mean tree height** ***Acacia tortilis*** **(Samar)**

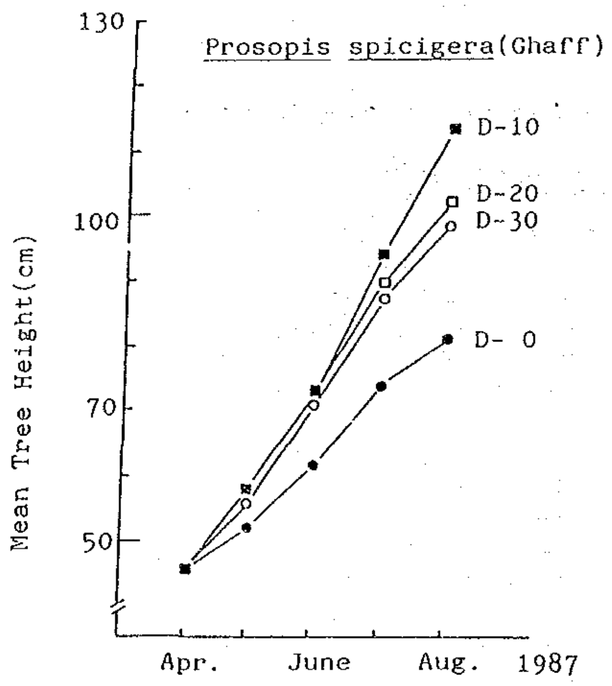


Fig. 16. **Monthly mean tree height** ***Prosopis spicigera*** **(Ghaff)**

Table 13. **Result of t-test in 5% significant level**

O: Significance
X: No Significance

Tree Height from the Ground
Acacia Tortilis(Samar)

		D-10	D-20	D-30	D- 0
April	D-10		X	X	X
	D-20			X	O
	D-30				X
	D- 0				
		D-10	D-20	D-30	D- 0
May	D-10		X	X	X
	D-20			X	O
	D-30				X
	D- 0				
		D-10	D-20	D-30	D- 0
June	D-10		X	X	X
	D-20			O	O
	D-30				X
	D- 0				
		D-10	D-20	D-30	D- 0
July	D-10		X	X	X
	D-20			O	O
	D-30				X
	D- 0				
		D-10	D-20	D-30	D- 0
August	D-10		X	X	O
	D-20			O	O
	D-30				X
	D- 0				

Table 14. **Result of t-test in 5% significant level**

O: Significance
X: No Significance

Tree Height from the Ground
Prosopis spicigera(Ghaff)

		D-10	D-20	D-30	D- 0
April	D-10		X	X	X
	D-20			X	X
	D-30				X
	D- 0				
		D-10	D-20	D-30	D- 0
May	D-10		X	X	O
	D-20			X	O
	D-30				X
	D- 0				
		D-10	D-20	D-30	D- 0
June	D-10		X	X	O
	D-20			X	O
	D-30				O
	D- 0				
		D-10	D-20	D-30	D- 0
July	D-10		X	X	O
	D-20			X	O
	D-30				O
	D- 0				
		D-10	D-20	D-30	D- 0
August	D-10		O	O	O
	D-20			X	O
	D-30				O
	D- 0				

Table 15. Result of the measurement for diameter in the height of 10 cm from the ground

Acacia tortilis (Samar)

Month		D - 10	D - 20	D - 30	D - 0
April	Mean (cm)	0.40	0.48	0.43	0.38
	Variance	0.00979	0.01584	0.00849	0.00761
	Number	71	70	70	72
May	Mean (cm)	0.47	0.48	0.47	0.42
	Variance	0.01479	0.01160	0.00594	0.00746
	Number	72	72	72	70
June	Mean (cm)	0.54	0.54	0.53	0.46
	Variance	0.01689	0.01611	0.01217	0.00961
	Number	72	72	72	69
July	Mean (cm)	0.55	0.58	0.53	0.47
	Variance	0.01655	0.02171	0.00892	0.00822
	Number	72	71	72	69
August	Mean (cm)	0.58	0.56	0.51	0.45
	Variance	0.02183	0.02174	0.00844	0.00812
	Number	71	71	72	69

Table 16. Result of the measurement for diameter in the height of 10 cm from the ground

Prosopis spicigera (Gharf)

Month		D - 10	D - 20	D - 30	D - 0
April	Mean (cm)	0.24	0.24	0.22	0.23
	Variance	0.00240	0.00348	0.00226	0.00278
	Number	71	71	70	71
May	Mean (cm)	0.43	0.41	0.37	0.36
	Variance	0.00792	0.01000	0.00728	0.00651
	Number	72	69	72	71
June	Mean (cm)	0.71	0.64	0.58	0.50
	Variance	0.04299	0.02980	0.02509	0.01612
	Number	72	67	72	71
July	Mean (cm)	1.07	0.87	0.78	0.65
	Variance	0.09384	0.04776	0.04712	0.02879
	Number	72	67	72	71
August	Mean (cm)	1.47	1.16	1.04	0.83
	Variance	0.15611	0.07685	0.09779	0.05710
	Number	72	67	72	71

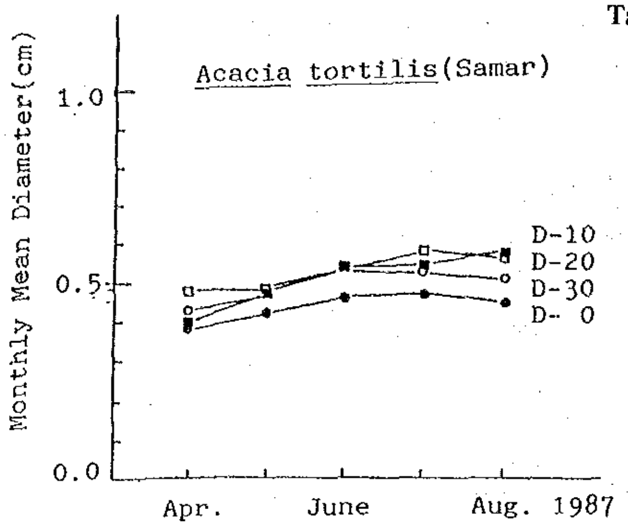


Fig. 17. **Monthly mean diameter**
Acacia tortilis **(Samar)**

Table 17. Result of t-test in 5% significant level

O: Significance
X: No Significance
Diameter in the Height of 10cm from the Ground
Acacia tortilis(Samar)

		D-10	D-20	D-30	D- 0
April	D-10		O	X	X
	D-20			O	O
	D-30				O
	D- 0				
May	D-10		X	X	O
	D-20			X	O
	D-30				O
	D- 0				
June	D-10		X	X	O
	D-20			X	O
	D-30				O
	D- 0				
July	D-10		X	X	O
	D-20			O	O
	D-30				O
	D- 0				
August	D-10		X	O	O
	D-20			O	O
	D-30				O
	D- 0				

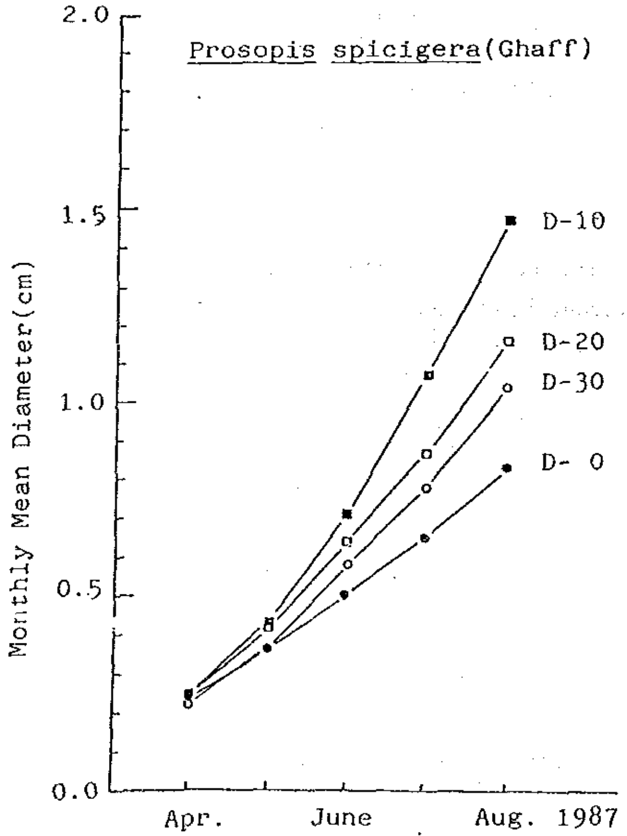


Fig. 18. **Monthly mean diameter**
Prosopis spicigera **(Ghaff)**

Table 18. Result of t-test in 5% significant level

O: Significance
X: No Significance
Diameter in the Height of 10cm from the Ground
Prosopis spicigera(Gharf)

		D-10	D-20	D-30	D- 0
April	D-10		X	O	O
	D-20			O	X
	D-30				X
	D- 0				
May	D-10		X	O	O
	D-20			O	O
	D-30				X
	D- 0				
June	D-10		O	O	O
	D-20			O	O
	D-30				O
	D- 0				
July	D-10		O	O	O
	D-20			O	O
	D-30				O
	D- 0				
August	D-10		O	O	O
	D-20			O	O
	D-30				O
	D- 0				

Table 19. Result of the measurement for crown diameter

Acacia tortilis (Samar)

Month		D - 10	D - 20	D - 30	D - 0
April	Mean(cm)	3.8	3.5	4.0	3.7
	Variance	1.4313	0.9964	3.4624	2.7423
	Number	71	70	70	72
May	Mean(cm)	19.8	17.3	16.8	10.6
	Variance	117.6200	104.5620	65.0891	52.8235
	Number	72	72	72	70
June	Mean(cm)	43.9	40.5	35.6	24.5
	Variance	268.3330	333.5170	193.3220	154.1050
	Number	72	72	72	69
July	Mean(cm)	56.7	50.3	42.7	33.5
	Variance	279.1580	437.9920	305.9900	183.1120
	Number	72	71	72	69
August	Mean(cm)	72.4	62.1	48.8	34.7
	Variance	366.1570	438.0420	378.7150	143.4170
	Number	71	71	72	69

Table 20. Result of the measurement for crown diameter

Prosopis spicigera (Ghaff)

Month		D - 10	D - 20	D - 30	D - 0
April	Mean(cm)	8.4	8.8	9.3	8.5
	Variance	9.9817	14.1322	11.4563	18.2885
	Number	71	71	72	71
May	Mean(cm)	43.2	41.2	38.3	27.2
	Variance	248.1790	280.8010	147.0690	135.3680
	Number	72	69	72	71
June	Mean(cm)	74.2	68.1	62.1	44.3
	Variance	483.1060	562.3880	371.1690	285.7460
	Number	72	67	72	71
July	Mean(cm)	109.5	89.3	80.6	60.0
	Variance	661.2860	641.3520	423.3220	401.9040
	Number	72	67	72	71
August	Mean(cm)	125.1	101.7	94.7	66.5
	Variance	748.8560	680.7160	628.1740	574.6010
	Number	72	67	72	71

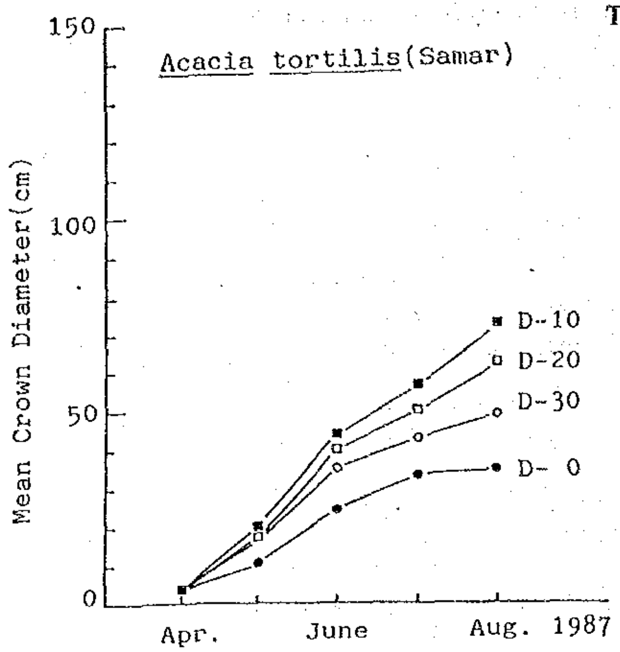


Fig. 19 **Monthly mean crown diameter** ***Acacia tortilis*** **(Samar)**

Table 21. Result of t-test in 5% significant level

O: Significance
X: No Significance
Crown Diameter
Acacia tortilis(Samar)

		D-10	D-20	D-30	D- 0
April	D-10		X	X	X
	D-20			X	X
	D-30				X
	D- 0				
May	D-10		X	X	O
	D-20			X	O
	D-30				O
	D- 0				
June	D-10		X	O	O
	D-20			X	O
	D-30				O
	D- 0				
July	D-10		O	O	O
	D-20			O	O
	D-30				O
	D- 0				
August	D-10		O	O	O
	D-20			O	O
	D-30				O
	D- 0				

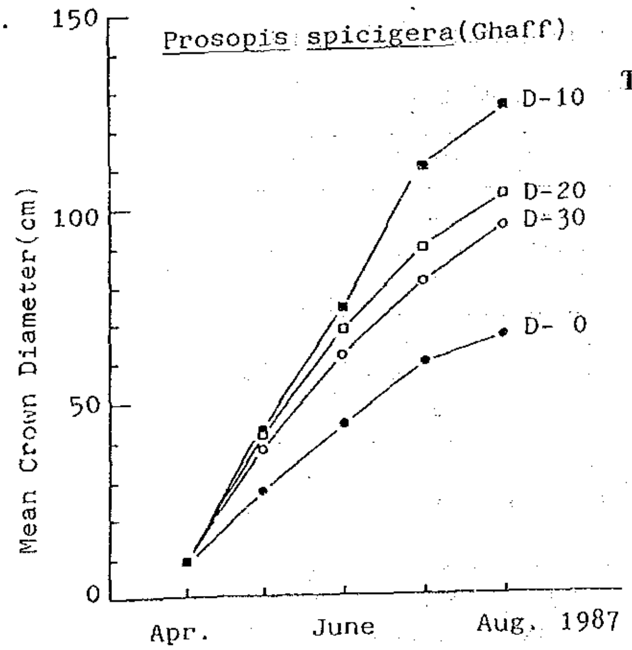


Fig. 20. **Monthly mean crown diameter** ***Prosopis spicigera*** **(Ghaff)**

Table 22. Result of t-test in 5% significant level

O: Significance
X: No Significance
Crown Diameter
Prosopis spicigera(Ghaff)

		D-10	D-20	D-30	D- 0
April	D-10		X	X	X
	D-20			X	X
	D-30				X
	D- 0				
May	D-10		X	O	O
	D-20			X	O
	D-30				O
	D- 0				
June	D-10		X	O	O
	D-20			X	O
	D-30				O
	D- 0				
July	D-10		O	O	O
	D-20			O	O
	D-30				O
	D- 0				
August	D-10		O	O	O
	D-20			X	O
	D-30				O
	D- 0				

Table 23. Covering area in each plot

Acacia tortilis (Samar)

Plot	April	May	June	July	August
D – 0	0.094	0.904	4.088	7.068	7.311
D – 10	0.089	2.882	12.417	19.979	31.246
D – 20	0.073	2.277	11.146	16.528	23.959
D – 30	0.105	1.971	8.243	12.032	15.580

Prosopis spicigera (Ghaff)

Plot	April	May	June	July	August
D – 0	0.506	4.873	12.508	22.281	27.824
D – 10	0.444	11.931	33.832	71.567	92.702
D – 20	0.514	10.697	27.385	45.356	57.972
D – 30	0.541	9.109	23.873	39.082	54.284

Samar + Ghaff

Plot	April	May	June	July	August
D – 0	0.600	4.967	16.596	29.349	35.135
D – 10	0.533	14.813	46.249	91.546	123.948
D – 20	0.587	12.974	38.531	61.884	81.931
D – 30	0.646	11.080	32.116	51.114	69.864

* unit : square meter

Table 24. Covering ratio in each plot

Acacia tortilis (Samar)

Plot	April	May	June	July	August
D – 0	0.003	0.025	0.114	0.196	0.203
D – 10	0.002	0.080	0.345	0.555	0.868
D – 20	0.002	0.063	0.310	0.459	0.666
D – 30	0.003	0.055	0.229	0.334	0.433

Prosopis spicigera (Ghaff)

Plot	April	May	June	July	August
D – 0	0.014	0.135	0.347	0.619	0.773
D – 10	0.012	0.331	0.940	1.988	2.575
D – 20	0.014	0.297	0.761	1.260	1.610
D – 30	0.015	0.253	0.663	1.086	1.508

Samar + Ghaff

Plot	April	May	June	July	August
D – 0	0.017	0.160	0.461	0.815	0.976
D – 10	0.014	0.411	1.285	2.543	3.443
D – 20	0.016	0.360	1.071	1.570	2.276
D – 30	0.018	0.308	0.892	1.420	1.941

* unit : (%)

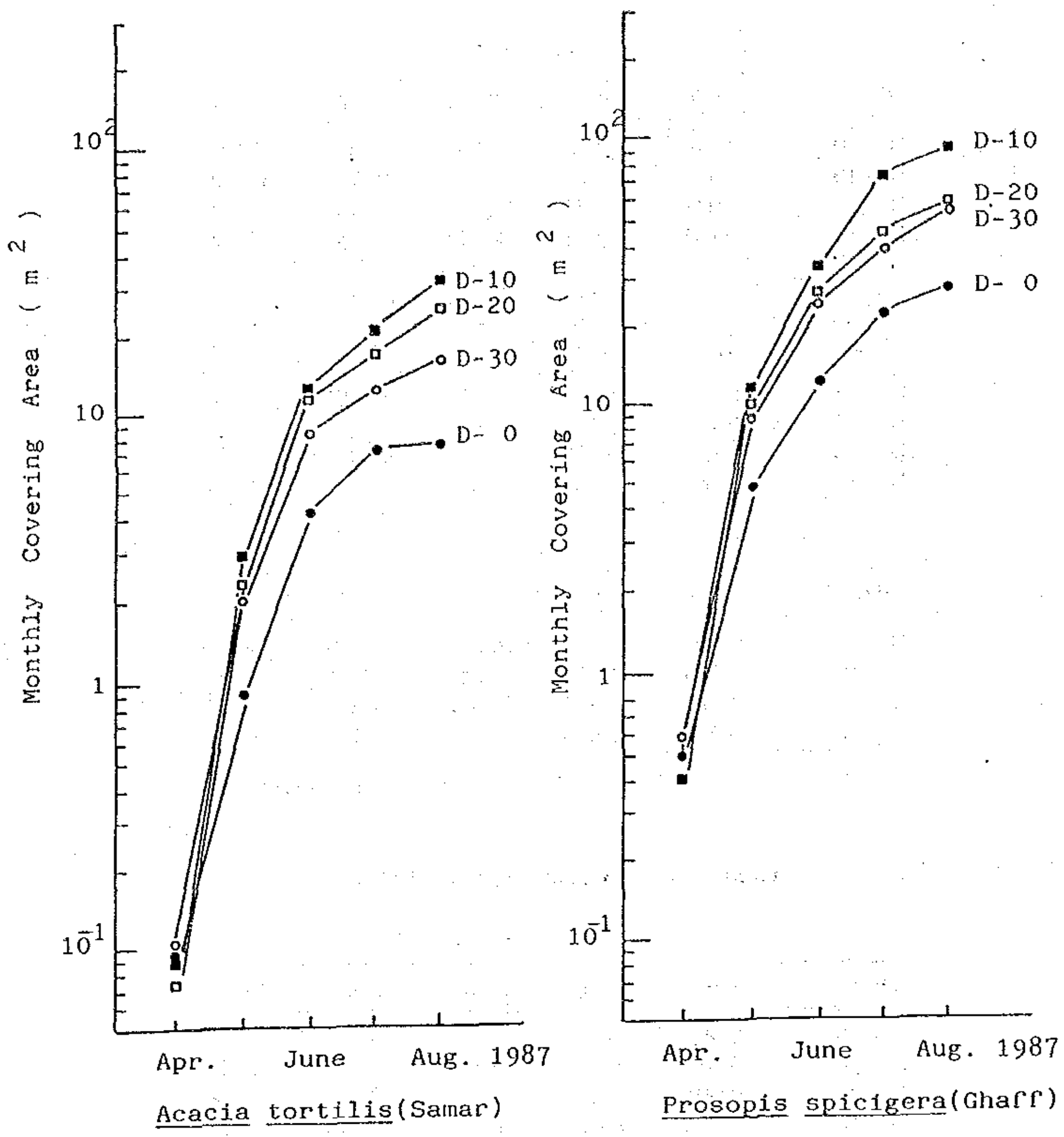


Fig. 21. Monthly covering area in each species

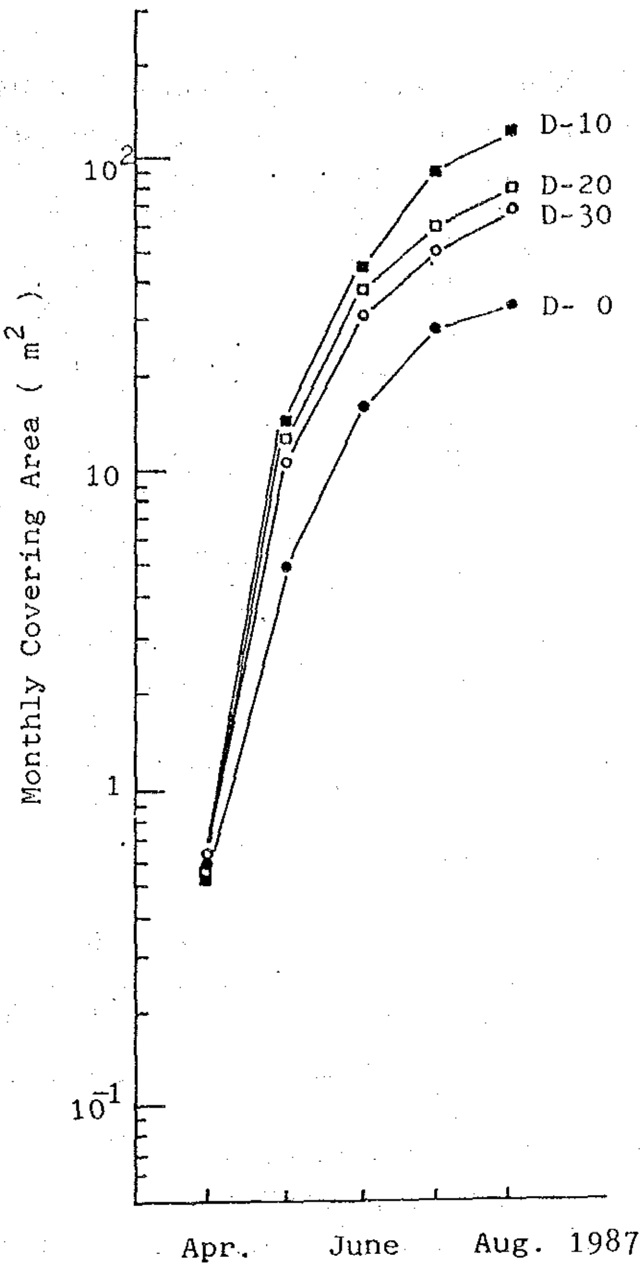


Fig. 22. Monthly covering area in each plot

Table 25. Number of dead tree and death ratio in each plot

Plot	Species	Number of Death in April	Death Ratio in April (%)	Number of Death May	June	July	Aug.	Death Ratio May-Aug. (%)
D-10	Samar	1		0	0	0	1	
	Ghaff	1		0	0	0	0	
	Total	2	1.39	0	0	0	1	0.69
D-20	Samar	2		0	0	1	0	
	Ghaff	1		3	2	0	0	
	Total	3	2.08	3	2	1	0	4.17
D-30	Samar	2		0	0	0	0	
	Ghaff	2		0	0	0	0	
	Total	4	2.78	0	0	0	0	0.00
D- 0	Samar	0		2	1	0	0	
	Ghaff	1		0	0	0	0	
	Total	1	0.69	2	1	0	0	2.08

* Number of Planted Trees in each Plot
  Samar 72 , Ghaff 72 , Total 144
* Death Ratio(%) = Number of Death / 144 x 100

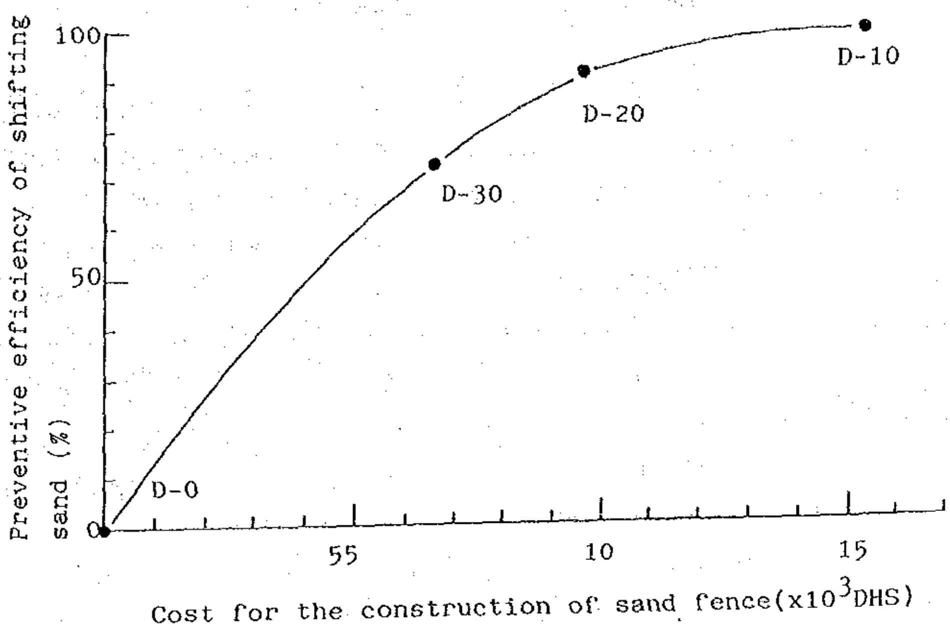


Fig. 24. **Relationship between the prevention of shifting sand and the cost for the construction of sand fence**

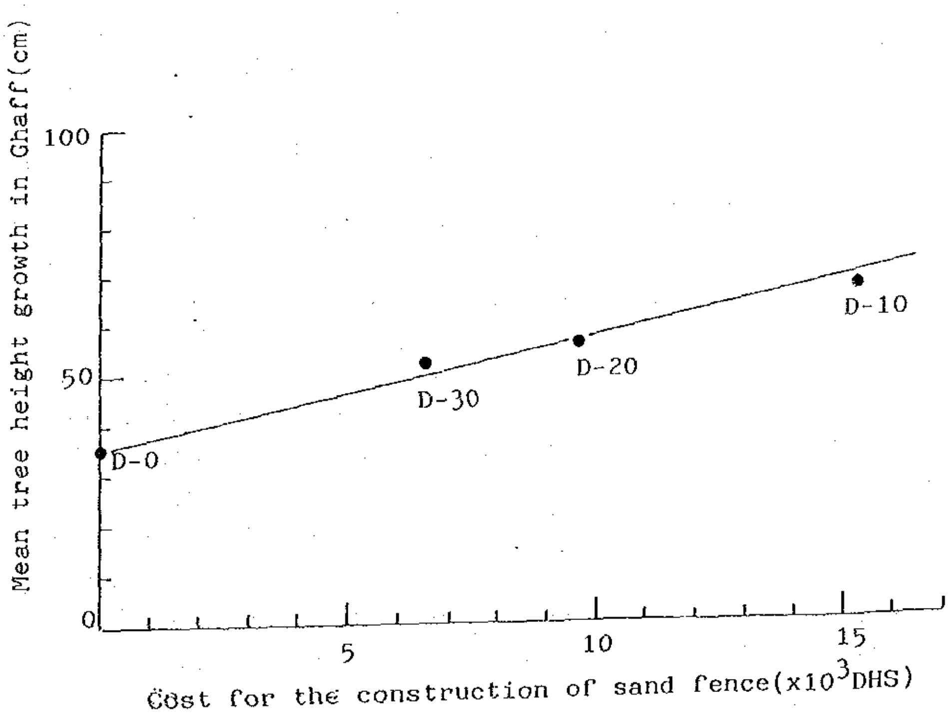


Fig. 25. **Relationship between mean tree height growth in Ghaff and the cost for the construction of sand fence**

Table 26. Cost benefit of sand fence

	Cost for the construction of sand fence (DHS)	Preventive efficiency of shifting sand (%)	Mean tree height growth in Ghaff from April to August (cm)
D- 0	0	0	35.4
D-30	6566.8	72.7	52.6
D-20	9661.7	91.3	56.3
D-10	15322.5	99.1	67.8

(4) Observations on Tree Growth Conditions in Afforestation Area in UAE

ABSTRACT

Tree growth of *Acacia tortilis* (Samar), *Prosopis spicigera* (Ghaff) and *Salvadora persica* (Arak) was measured at Al Wagon afforestation area. The tree height of Samar, Ghaff and Arak increased from shortly after transplanting till November, followed by little increase in winter season, then resumed to increase from February or March. Soil salinity in main root zone did not increase very much even though the trees were irrigated with relatively high saline water (EC = 11.3 mS/cm).

The tree growth of *Inga edvlis* (Ghaff bahar), *Prosopis spicigera* and *Zizyphus jujuba* (Sidar) was also measured at Al Oha University Experimental Farm. The rapid growth of Ghaff bahar affected the growth of Ghaff and Sidar.

INTRODUCTION

UAE Government has been emphasizing on afforestation in all over the country. The main objective of afforestation in this area is to prevent sand movement in order to protect living areas, roads and farms. There are lots of tree planting projects in UAE, but unfortunately, numerical or statistical data is rarely available concerning tree growth, growth condition and effects of afforestation on desertification. This observation has been carring out in order to survey tree growth condition in the afforestation area in UAE.

Observation 1 :

Observation of Tree Growth at Al Wagon Afforestation Area

MATERIALS AND METHODS

The observation site was planted by Al Ain Forestry Department at Al Wagon area, 80 km south-west from Al Ain.

Young seedlings of *Acacia tortilis* (Samar), *Prosopis spicigera* (Ghaff) and *Salvadora percia* (Arak) were transplanted in April and May 1986. The distance between trees was 7 m, and total planted area was 300 ha. EC and pH of irrigation water was 11.30 mS/cm and 7.7, respectively.

Height and diameter of trees were measured monthly by stake ruler and vernier caliper, respectively. EC and pH of soil saturation extracts and soil moisture were also measured periodically. Soil samples were taken from 0–1, 1–10, 10–30, 30–50, 50–70 and 70–100 cm below soil surface, respectively.

RESULTS AND DISCUSSION

I. Tree growth

(1) *Acacia tortilis* (Samar)

Fig. 1 shows the change in tree height and trunk diameter of *Acacia tortilis*. Tree height increased rapidly shortly after transplanting (June, 1986) till November, followed by little increase till March, and then increased remarkably after that.

On the other hand, trunk diameter increased gradually from June to January, followed by relatively rapid increase till August.

(2) *Prosopis spicigera* (Ghaff)

Fig. 2 shows the change in tree height and trunk diameter of *Prosopis spicigera*. Tree height and trunk diameter increased rapidly from June to November, followed by little increase till February, then increased again after that.

(3) *Salvadora persica* (Arak)

Fig. 3 shows the changes in tree height and trunk diameter of *Salvadora persica*. Tree height and trunk diameter increased rapidly from June to November, followed by little increase till January, then increased again after that.

II. Soil salinity

The change of EC of soil saturation extracts in three different investigated area (plot 1, plot 2 and plot 3) are shown in Fig. 4, Fig. 5 and Fig. 6. EC of surface soil was extremely higher than other layers, but sometimes decreased rapidly, due to the removal of the salinized soil around tree. EC of other lower layers was relatively low in spite of irrigated high salinity water (EC = 11.3 mS/cm), which is due to leaching process. Planted trees were irrigated with high amount approximately 40 litre/day), consequently salts did not accumulated very much in root zone.

Observation 2 :

Observation on Tree Growth of Windbreak Trees at Al Oha University Farm

MATERIALS AND METHOD

Young seedlings of *Tamalix articulata* and *Inga edvlis* (Ghaff bahar) were transplanted in April and May 1986 around the University Farm, and were irrigated by drip irrigation system. The distance between trees was 2 m and the distance between lines was 1 m. However, *Prosopis spicigera* (Ghaff) and *Zizyphus jujuba* (Sidar) were transplanted in place of *Tamalix articulata* in October 1986. Tree growth of these three species, *Inga edvlis, Prosopis spicigera* and *Zizyphus jujuba,* measured monthly from 27 October 1986. Tree height and diameter were measured. EC of irrigation water was apploximately 1.5 mS/cm.

RESULTS AND DISCUSSION

Change of tree height and trunk diameter of each species are shown in Fig. 7, Fig. 8 and Fig. 9. *Inga edvlis* grew very well, and its height reached 243 cm in average after 16 months from the transplanting. On the other hand, the tree height of *Prosopis spicigera* and *Zizyphus jujuba* showed little increase throughout the measurement period. It is considered that the growth of *Prosopis spicigera* and *Zizyphus jujuba* was affected by rapid growth of *Inga edvlis*, since they were planted adjacent to each other.

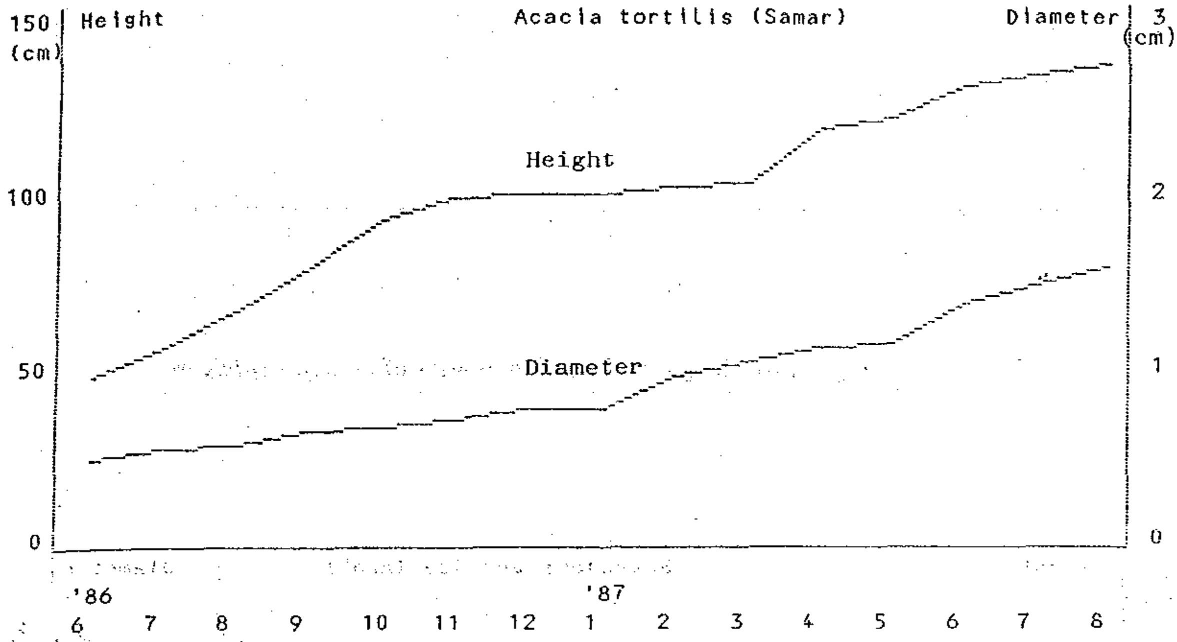


Fig. 1. Change in tree height and trunk diameter of *Acacia tortilis*

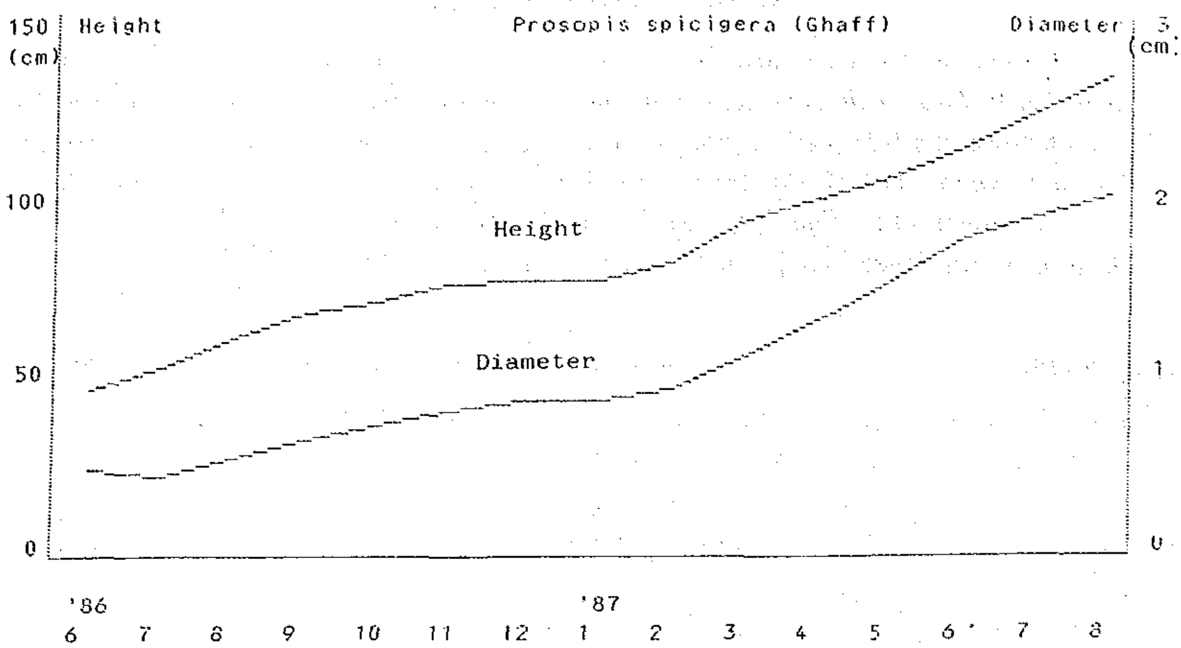


Fig. 2. Change in tree height and trunk diameter of *Prosopis spicigera*

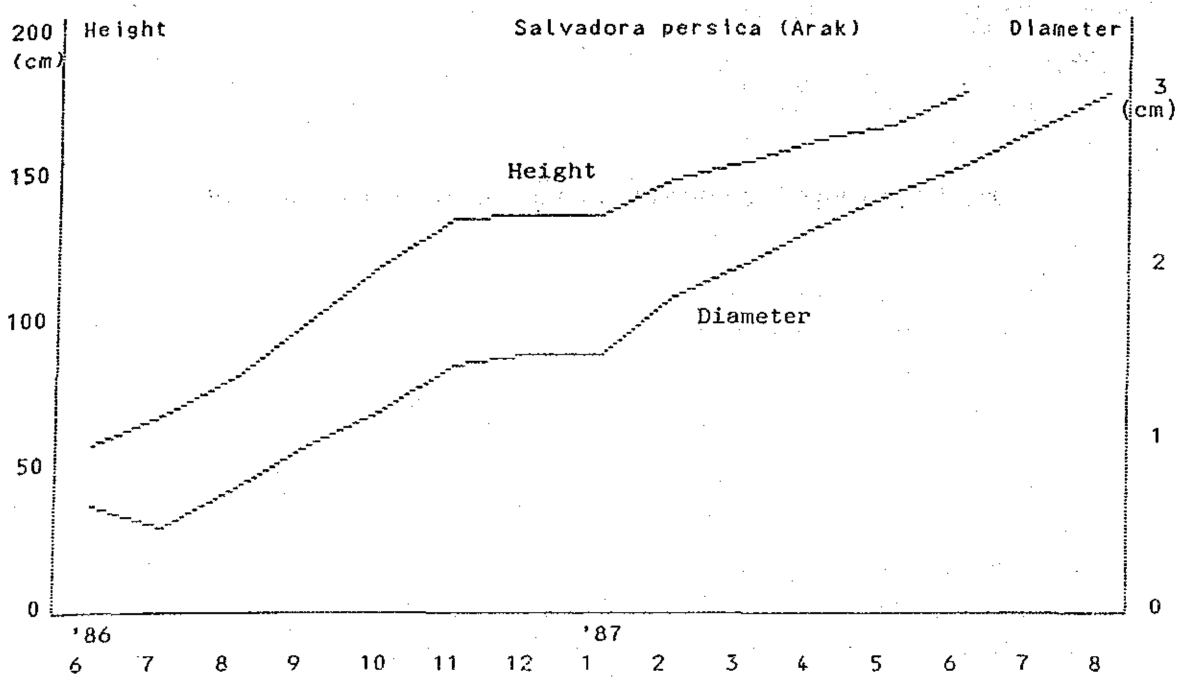


Fig. 3. Change in tree height and trunk diameter of *Salvadora persica*

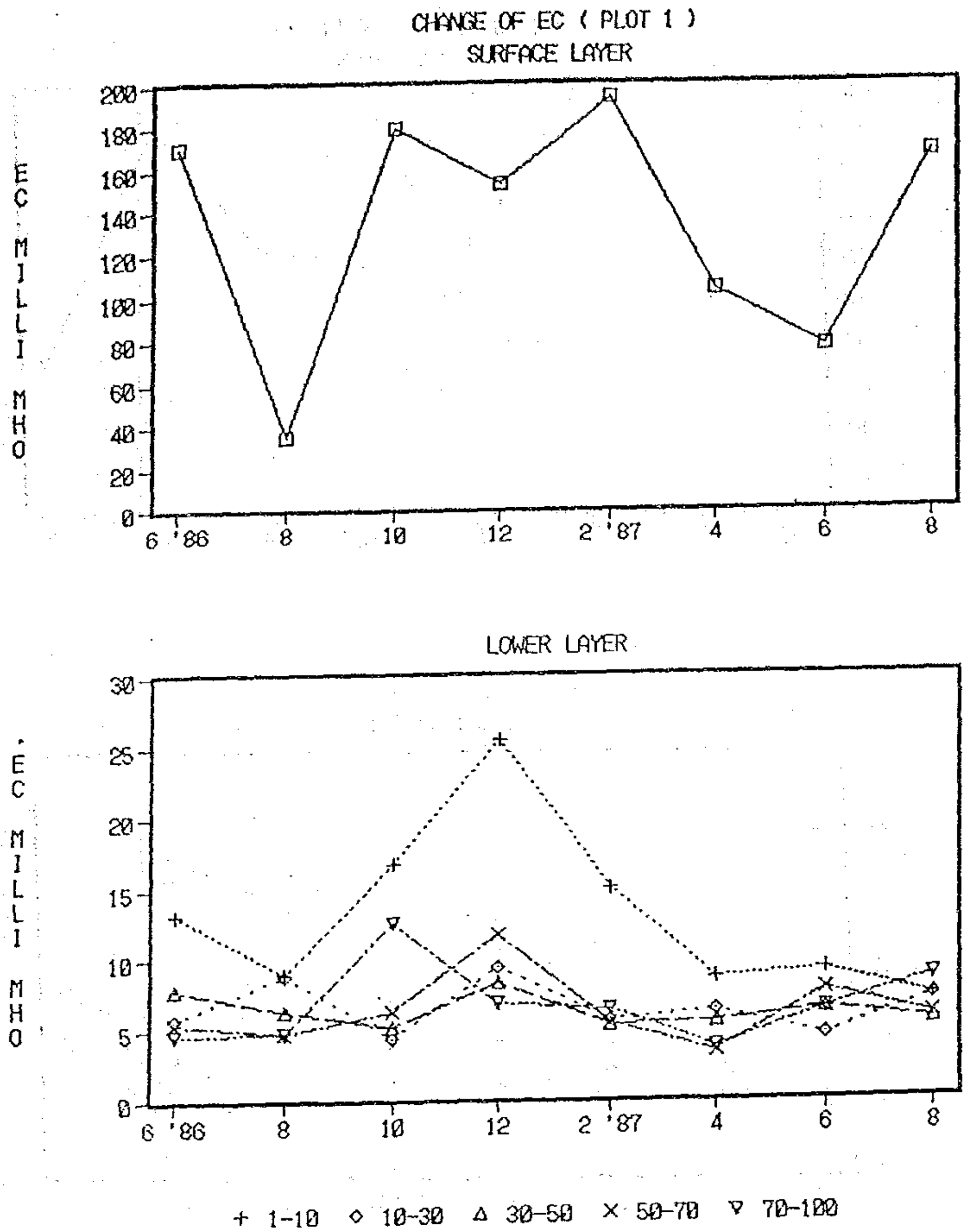


Fig. 4. Change in EC of different soil layers (plot 1)

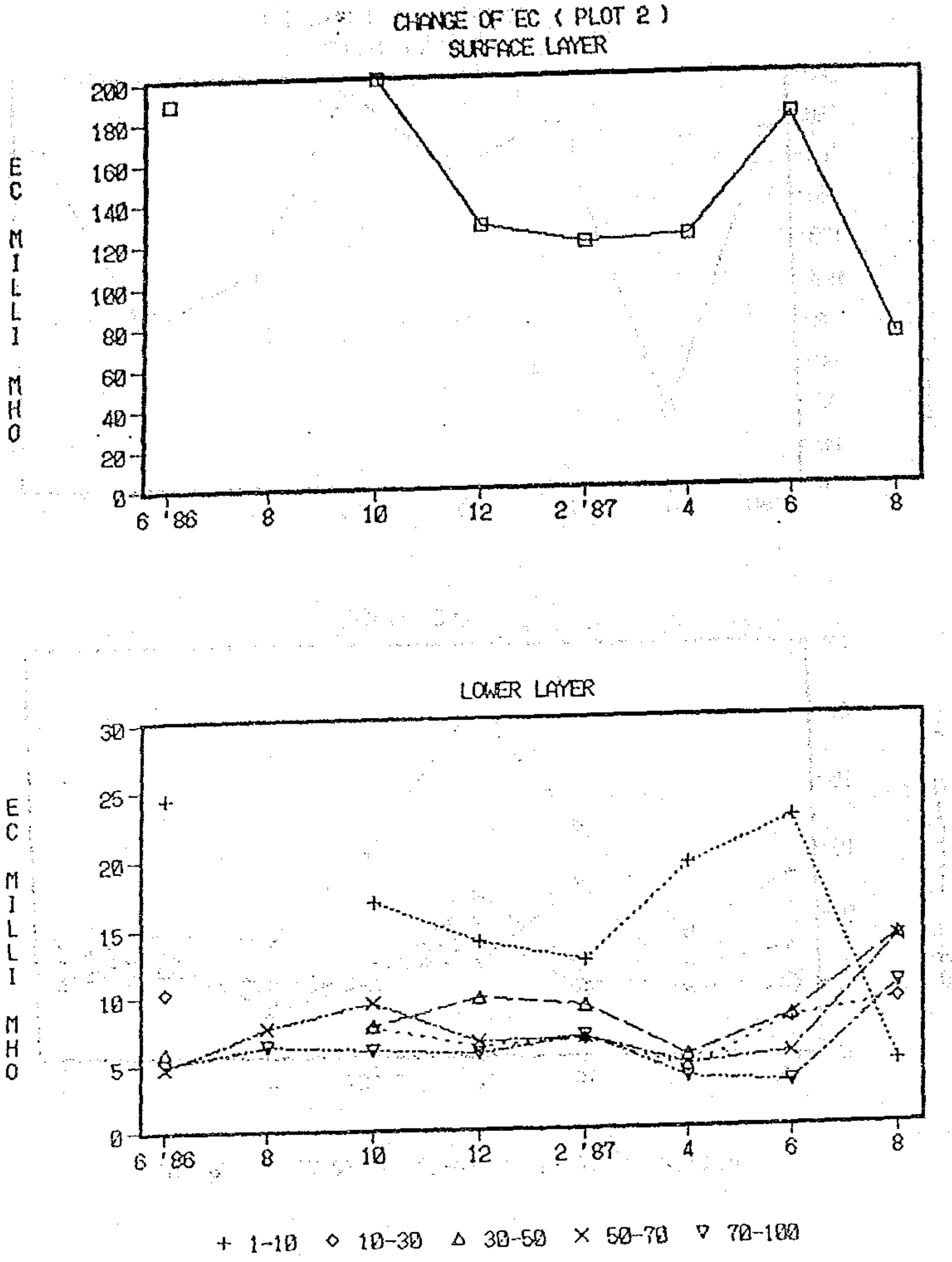


Fig. 5. Change in EC of different soil layers (plot 2)

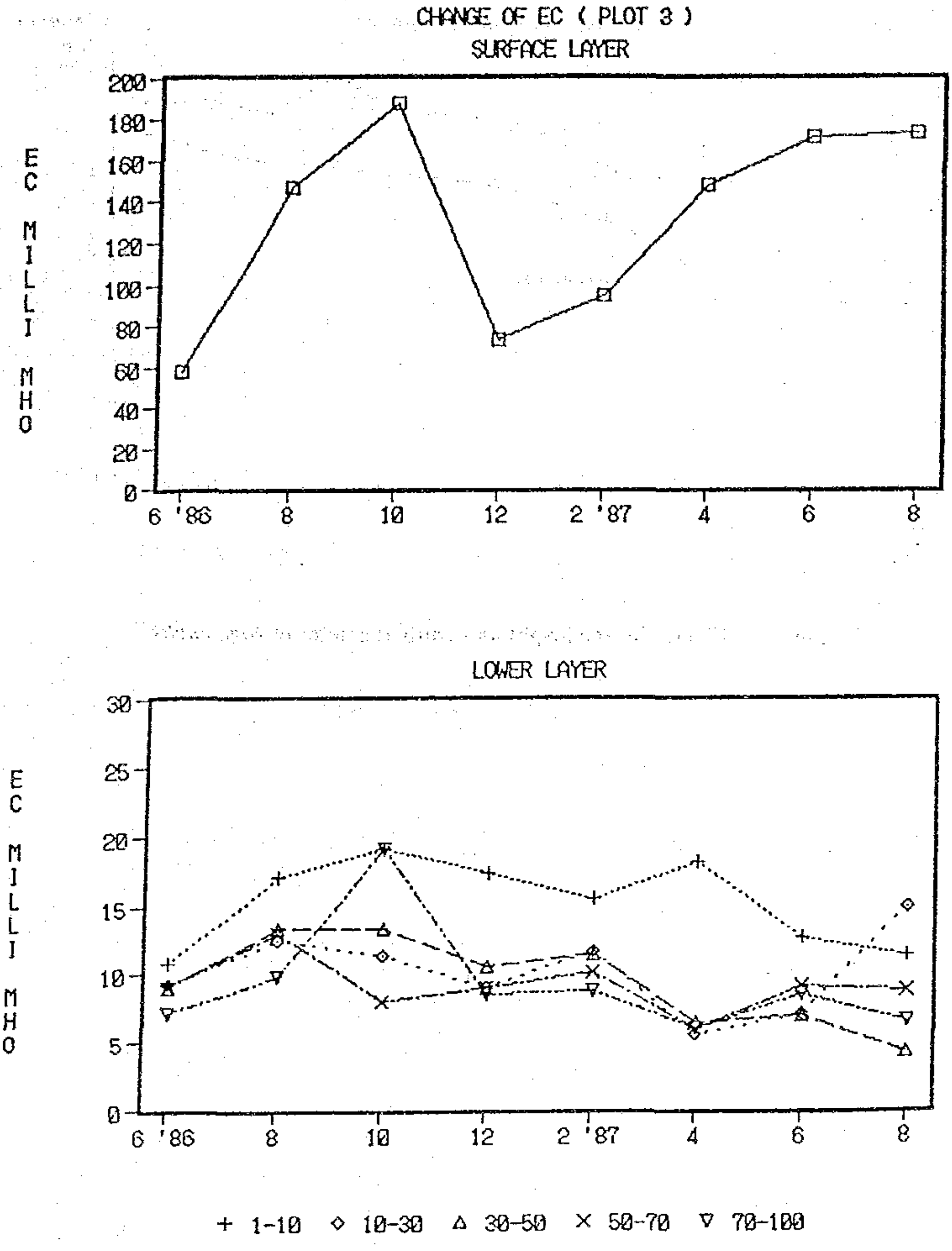


Fig. 6. Change in EC of different soil layers (plot 3)

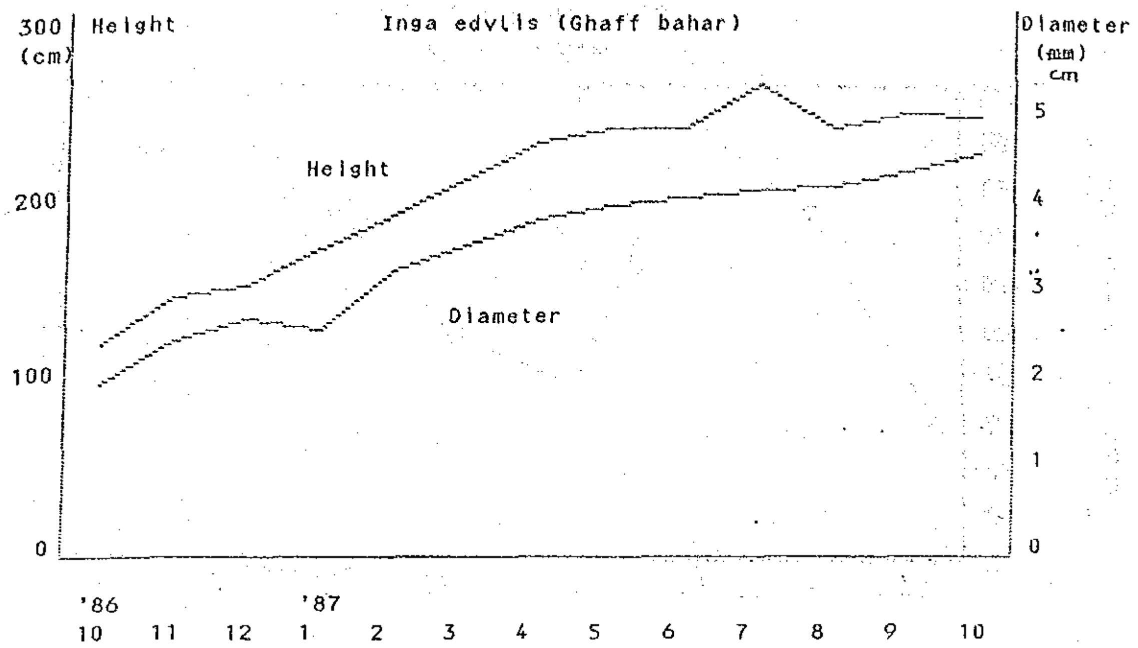


Fig. 7. **Change in tree height and trunk diameter of *Inga edvlis***

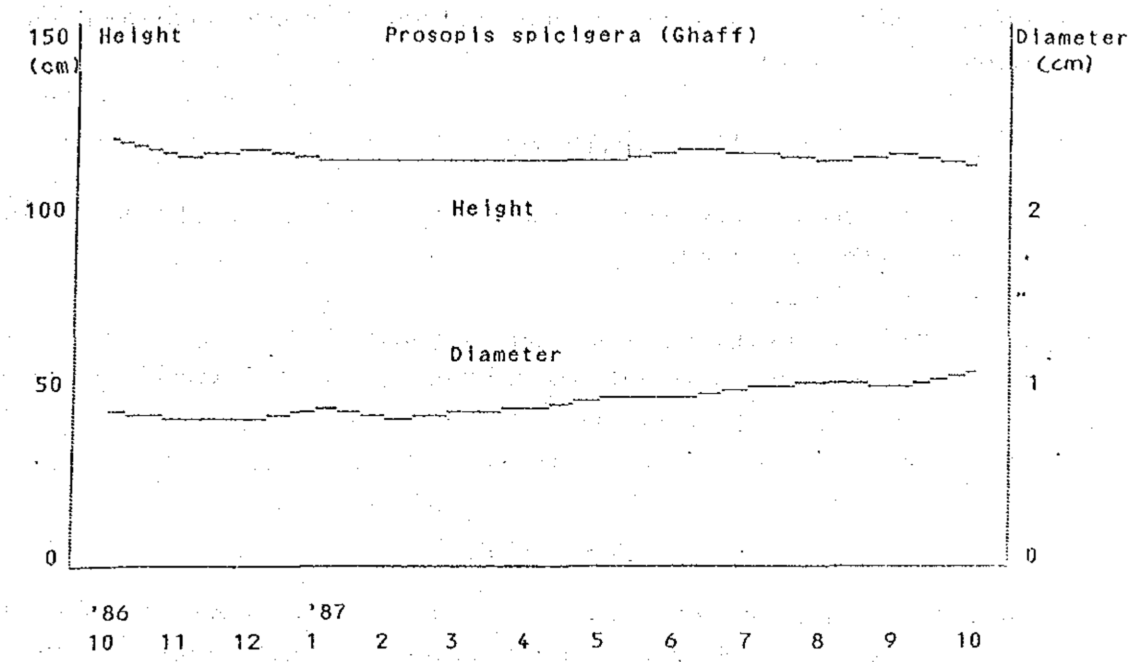


Fig. 8. Change in tree height and trunk diameter of *Prosopis spicigera*

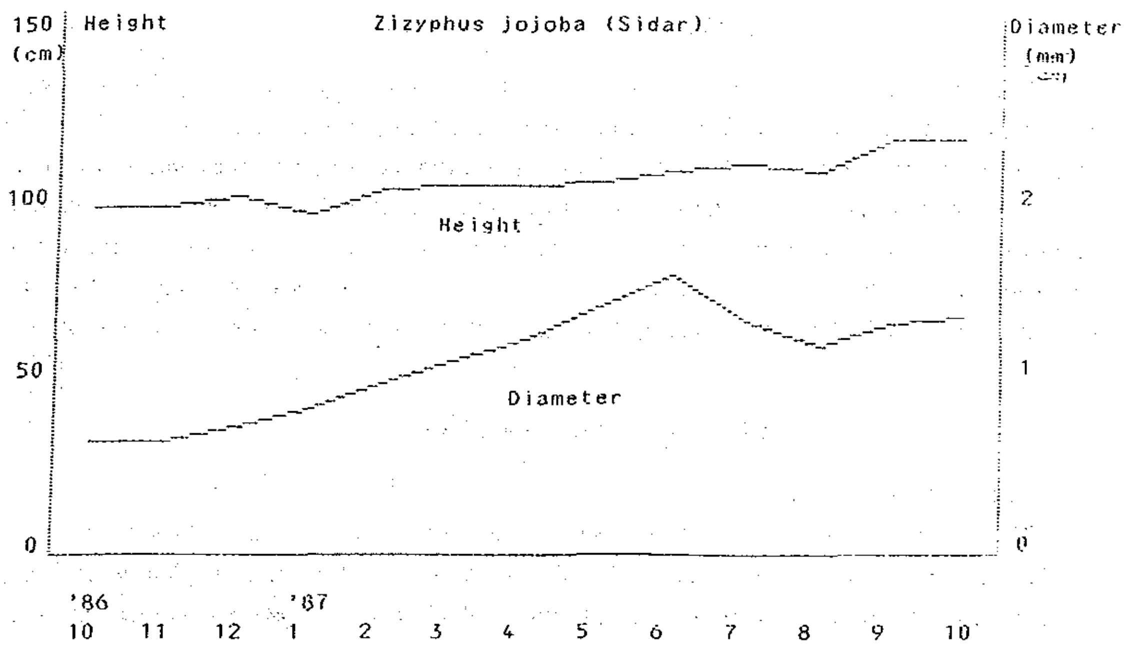


Fig. 9. Change in tree height and trunk diameter of *Zizyphus jujuba*

(5) Effect of Different Transplanting Month on the Growth of *Acacia tortilis* (Samar) and *Prosopis spicigera* (Ghaff)

ABSTRACT

Monthly tree planting was carried out to determine suitable transplanting time of *Acacia tortilis* and *Prosopis spicigera.*

The following were estimated :

1) Trees transplanted in winter season did not grow properly.

2) Stormy wind was experienced at the seasonal turning point, which seemd to affect the high rate of dead seedlings or poor growth after transplanting.

The measurement will be continued for one more year.

INTRODUCTION

There are several factors which relate to good management of afforestation. Time of transplanting trees is one of the most important factors to have good growth. This study was carried out to determine the most suitable time for transplanting *Acacia tortilis* (Samar) and *Prosopis spicigera* (Ghaff), which are the most popular species in UAE.

MATERIALS AND METHODS

Each ten seedlings of *Acacia tortilis* (Samar) and *Prosopis spicigera* (Ghaff) were transplanted once per moth. The first ten trees were transplanted on 23 June 1986. Tree transplanting was continued till 23 May 1987. The distance between trees was 1 m. Irrigation water was supplied by tanker in early stage, and drip irrigation system was installed in July 1987. The EC of irrigation water was approximately 1.5 mS/cm. Due to shortage of irrigation water, the seedlings which were planted in even months were eliminated several month after transplanting. Tree height, diameter and crown area were measured monthly.

RESULTS AND DISCUSSION

I. *Acacia tortilis* (Samar)

The change of tree height, trunk diameter and crown area of *Acacia tortilis* are shown in Fig. 1, Fig. 2 and Fig. 3, respectively. The seedlings which were transplanted in June, July, August and September grew well, but those which were transplanted in other months did not show good growth up to August 1987.

Table 1 shows rate of dead seedlings after three months of transplanting. The rate was 30% in September and 10% in April.

II. *Prosopis spicigera* (Ghaff)

The change of tree height, trunk diameter and crown area of *Prosopis spicigera* (Ghaff) are shown in Fig. 4, Fig. 5 and Fig. 6, respectively. The results are similar to those of *Acacia tortilis.* June-, July-, August- and September-planted seedlings showed better growth than others up to August 1987.

The rate of dead seedlings after three months of transplanting was 70% in August, 10% in November, January and May.

The followings are estimated :

1) Winter season is not suitable for transplanting, because growth of the seedlings were very poor.

2) Stormy wind was experienced at the seasonal turnig point, such as end of summer or winter, which scemes to after rate of dead seedlings or growth after transplanting.

This experiment is still going on, therefore the measurement will be continued for one more year.

Table 1. Rate of dead seedlings after 3 months of transplanting

Transplanting month	Rate of dead seedlings (%)	
	Acacia tortilis	Prosopis spicigera
JUN 1986	0	0
JUL	0	0
AUG	0	70
SEP	30	0
OCT	0	0
NOV	0	10
DEC	0*	0*
JAN 1987	0	10
FEB	0*	0*
MAR	0	0
APR	10	0
MAY	0	10

* : 2 months after transplanting

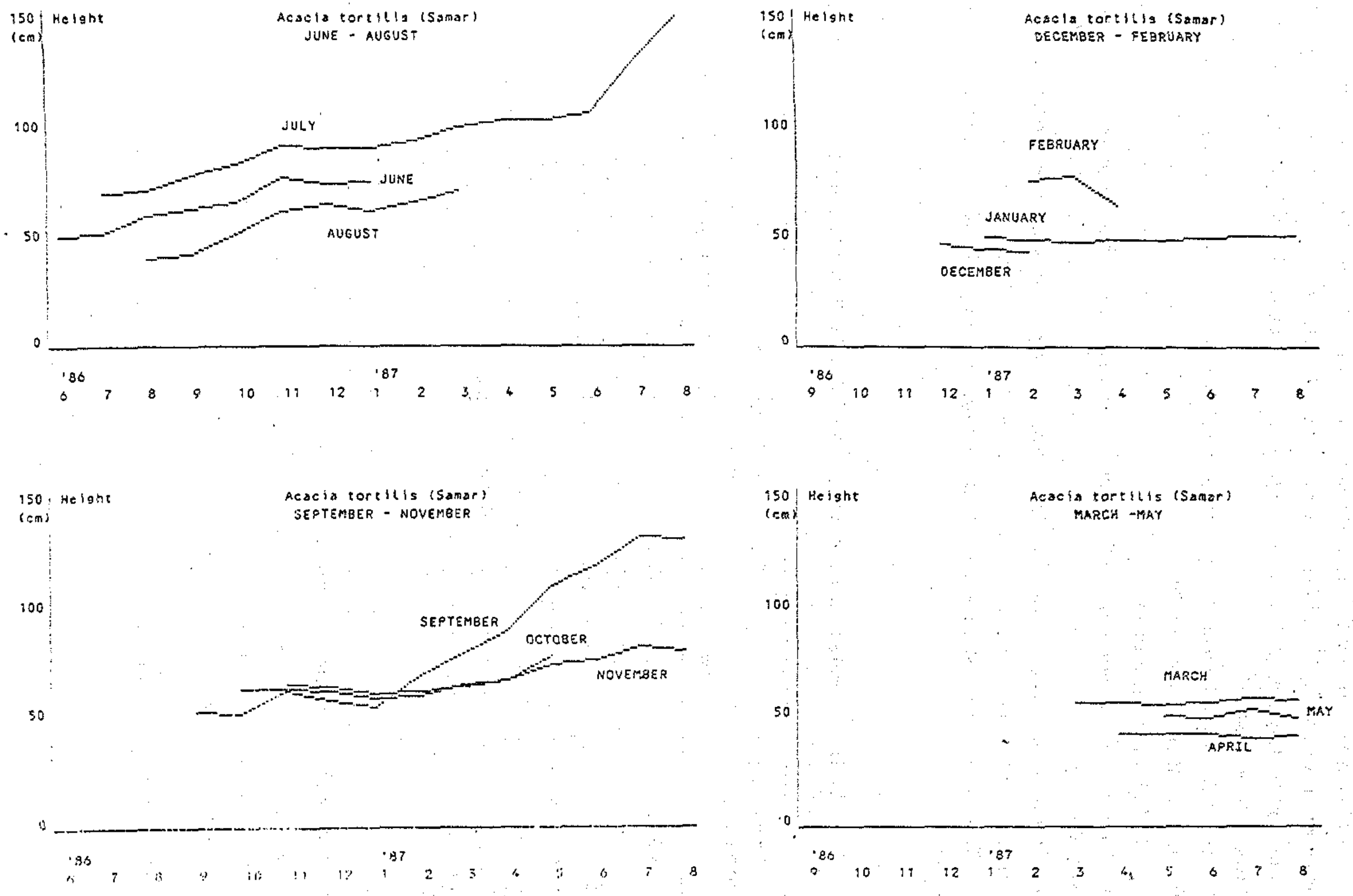


Fig. 1. Change of tree height of *Acacia tortilis*

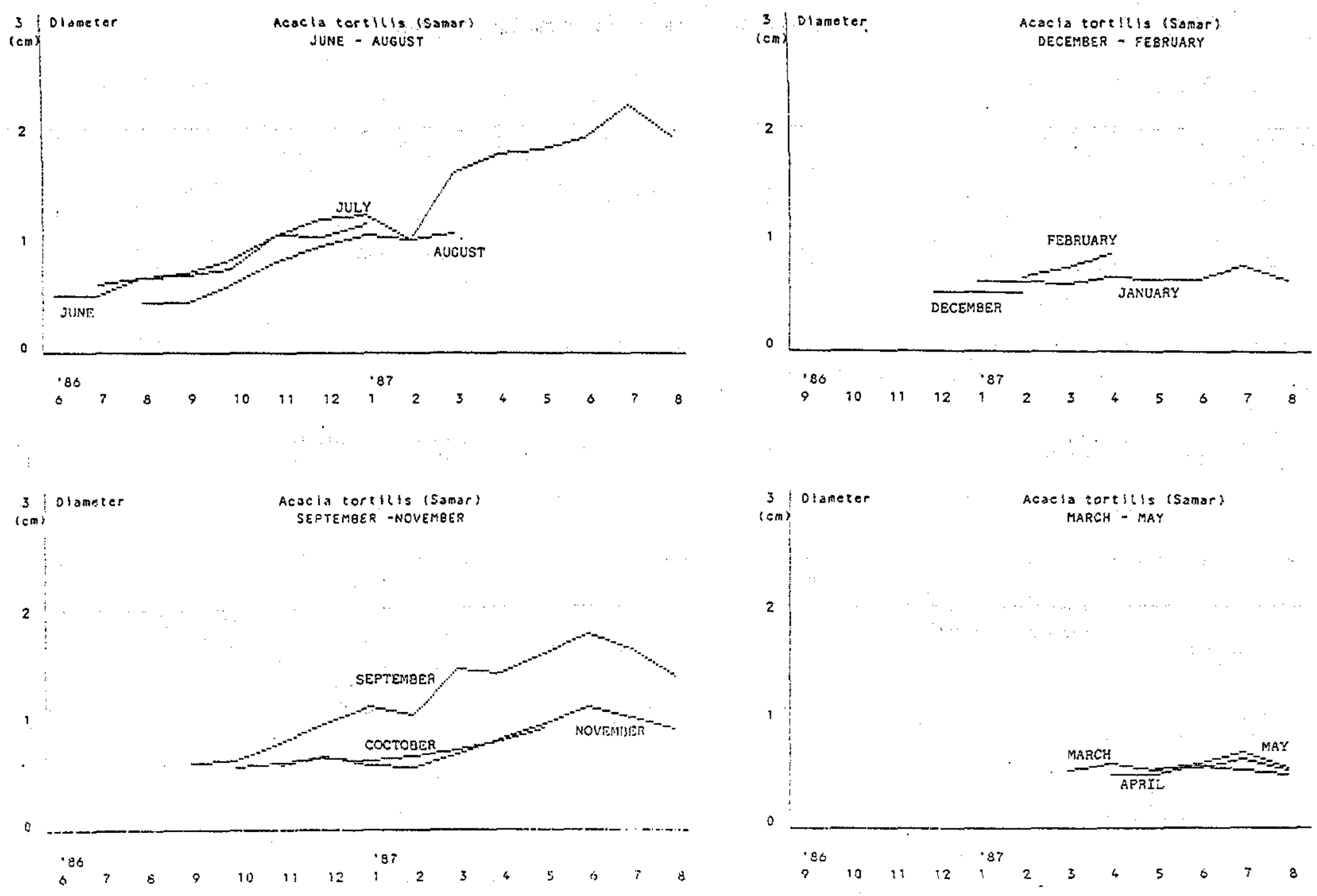


Fig. 2. Change of trunk diameter of *Acacia tortilis*

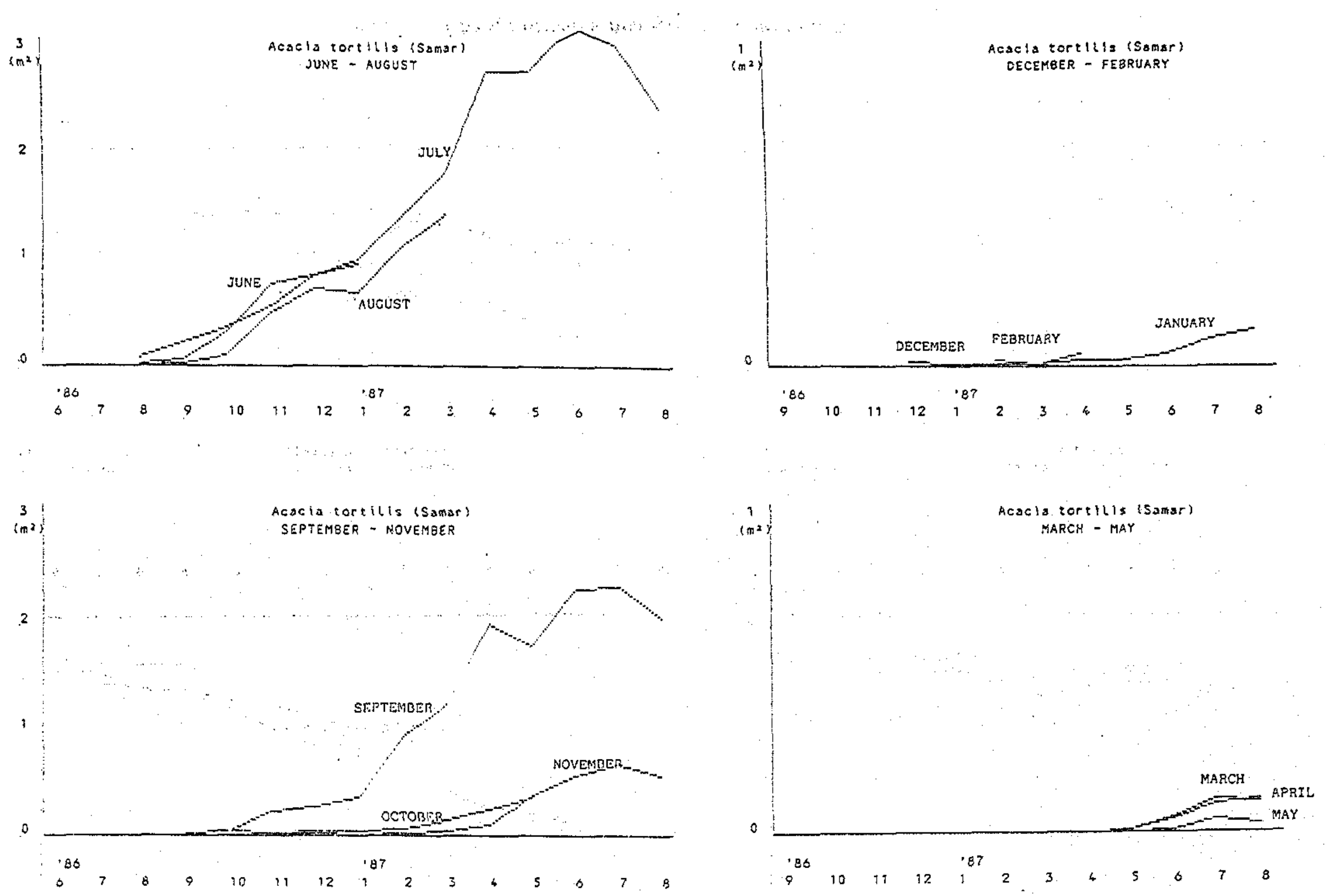


Fig. 3. Change of crown area of *Acacia tortilis*

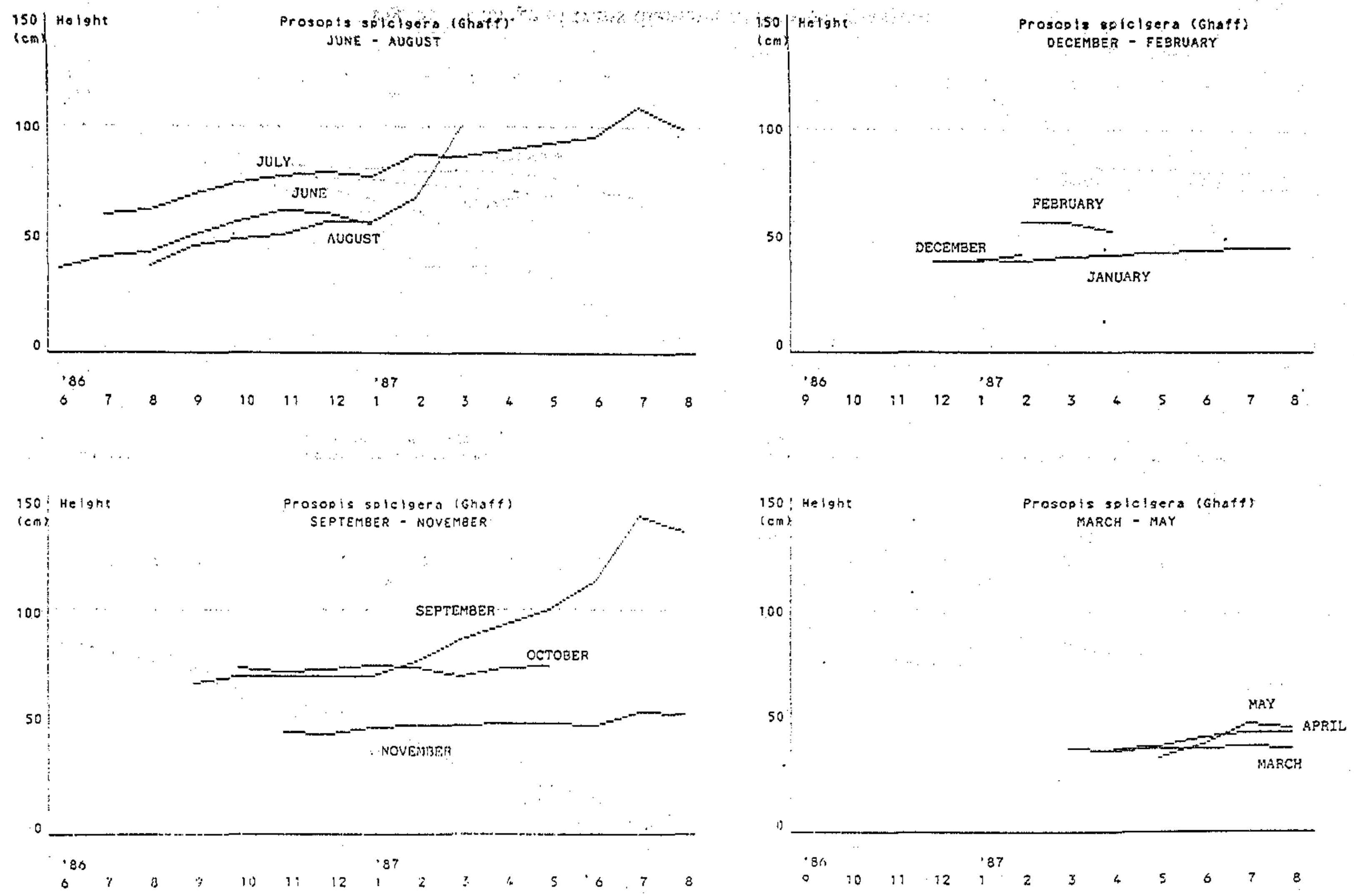


Fig. 4. Change of tree height of *Prosopis spicigera*

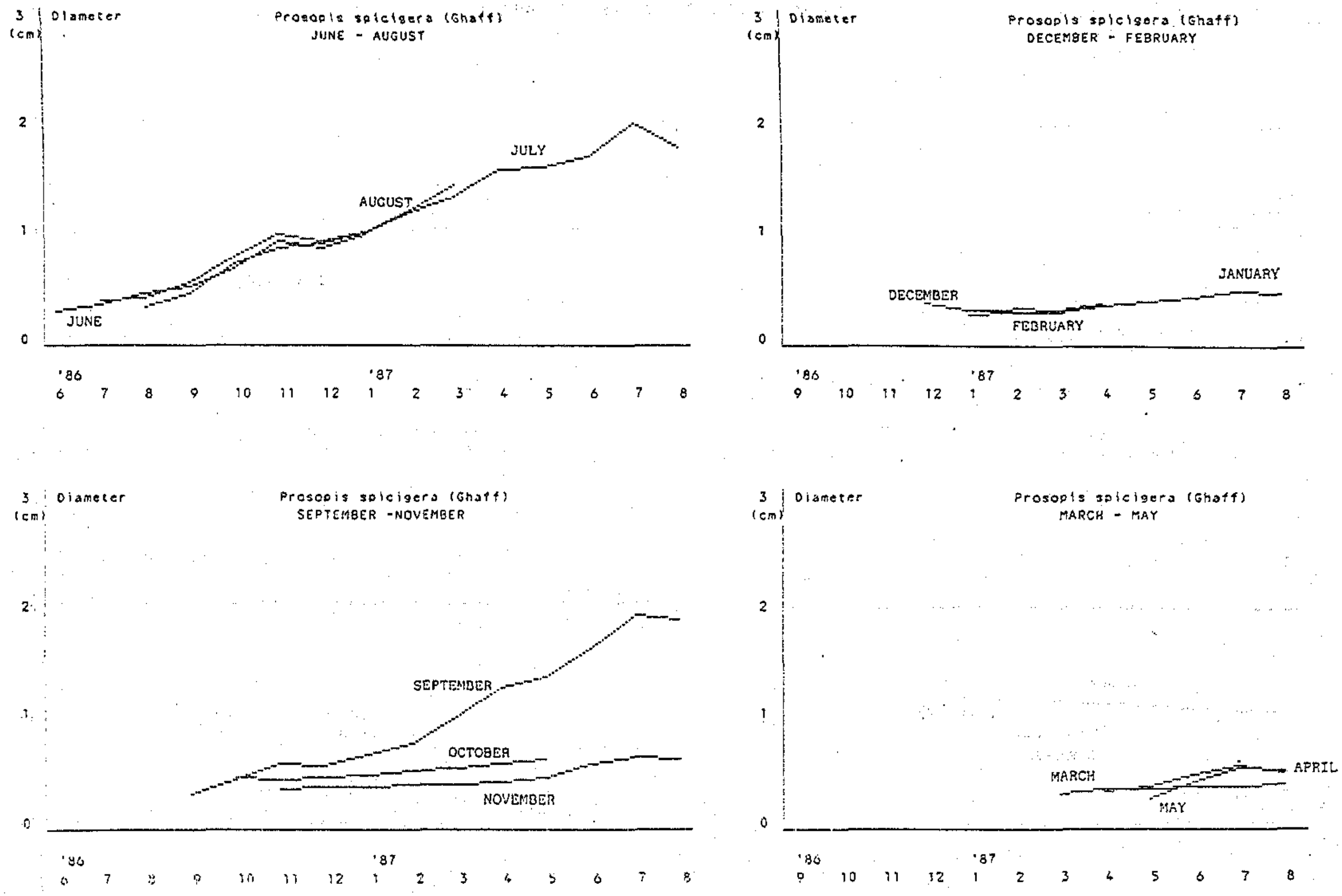


Fig. 5. Change of trunk diameter of *Prosopis spicigera*

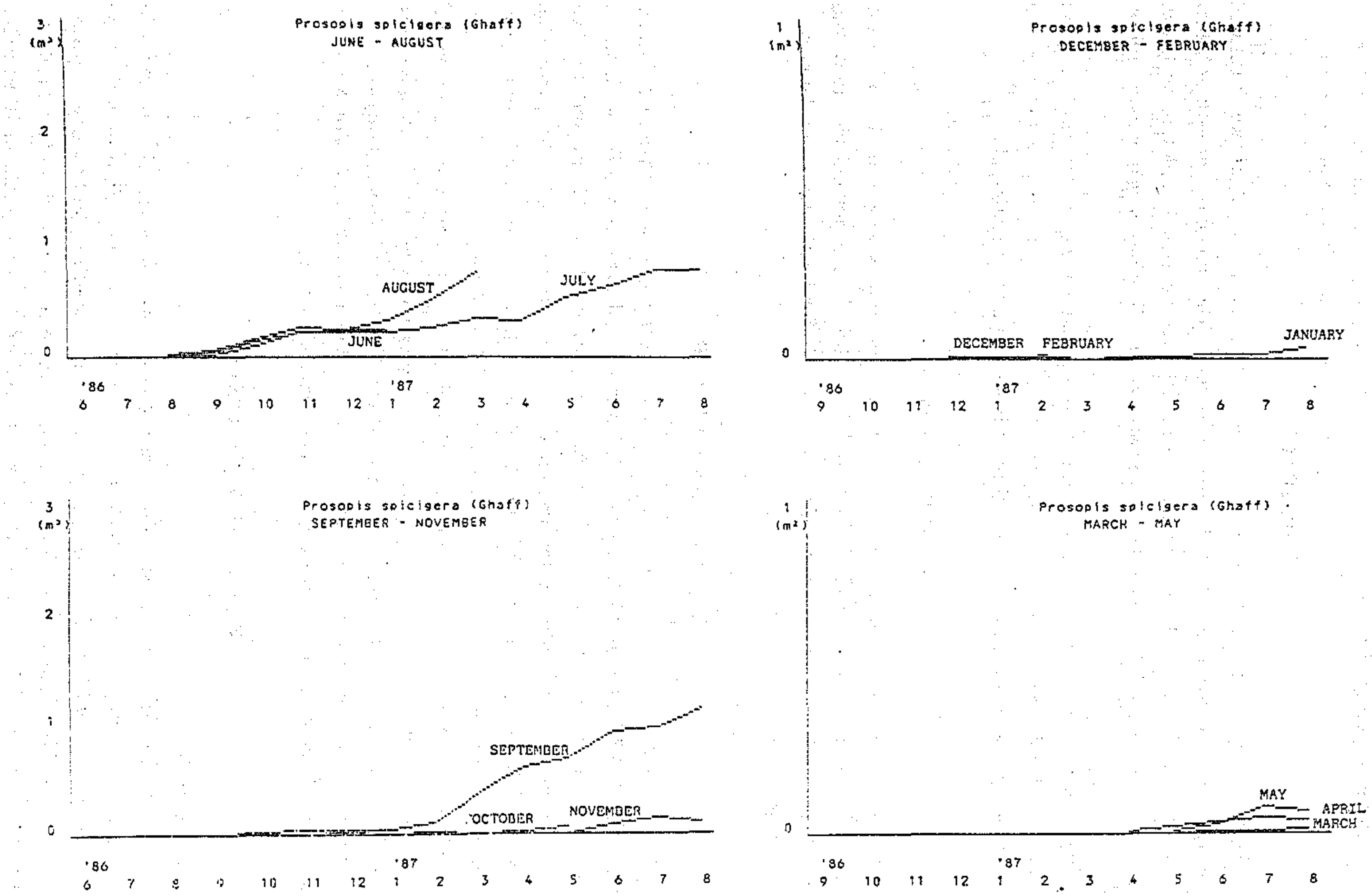


Fig. 6. Change of crown area of *Prosopis spicigera*

(6) Effect of Irrigation Water Amount on the Growth of *Acacia tortilis* (Samar) and *Prosopis spicigera* (Ghaff)

ABSTRACT

Three growth of *Acacia tortilis* (Samar) and *Prosopis spicigera* (Ghaff) was measured under two levels of irrigation water (5 ℓ/day and 10ℓ/day). The annual tree growth of Samar and Ghaff were 29.7 cm and 74.2 cm in average in 10 litre/day irrigation plot, respectively. In contrast, they were 2.6 cm and 37.7 cm in average in 5 litre/day irrigation plot, respectively.

Soil temperature at the different depth of 10 litre/day irrigation plot was lower and daily range of soil temperature was narrower than those of 5 litre/day irrigation plot, which are considered one of the reason of better growth in high amount irrigation plot.

INTRODUCTION

Water is essential for plant growth, and at the same time saving water is one of the most important matters especially in arid land agriculture. This preliminary study was conducted in order to investigate the effect of amount of irrigation water on the growth of *Acacia tortilis* and *Prosopis spicigera.*

MATERIALS AND METHODS

Young seedlings of *Acacia tortilis* (Samar) and *Prosopis spicigera* (Ghaff) were transplanted on 21 May 1986 at Al Oha villa's garden in Central Laboratory. Ten seedlings of each species were planted. 10 litre/day of water was irrigated to each seedling for two weeks. Treatment of irrigation water amount was initiated from 3 June 1986. Irrigation amount was 10 litre/tree/day in high amount plot and 5 litre/tree/day in low amount plot. EC and pH of irrigation water were 0.72 mS/cm and 8.2, respectively.

Tree growth was measured monthly by tree hight, trunk diameter and crown area. EC and pH of saturated extracts and soil moisture were measured regularly. Soil samples were collected from 0–1, 1–10, 10–30, 30–50, 50–70 and 70–100 cm below soil surface.

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

RESULT AND DISCUSSION

I. Tree growth

The change of tree height, trunk diameter and crown area of two species are shown in Fig. 1, Fig. 2 and Fig. 3, respectively. Table 1 shows tree height in each treatment at the beginning of the measurement and at one year after. Tre growth in 10 litre/day irrigation plot was better than that in 5 litre/day irrigation plot. Annual growth in tree height of *Acacia tortilis* and *Prosopis spicigera* were 29.7 cm and 74.2 cm in average in 10 litre/day irrigation plot, respectively. In contrast, in 5 litre/day irrigation plot, they were 2.6 cm and 37.7 cm in average, respectively. There is no significant difference between treatments, because number of samples was small (N = 5) and variance was large.

II. Soil temperature

Diurnal change of air temperature, water temperature and soil temperature at different soil depth are shown in Fig. 4, Fig. 5 and Fig. 6, respectively. Table 2 shows daily maximum, daily minimum and daily range of soil temperature. These data were collected on July 11, July 18 and July 25, 1986, and all figures are mean value of these three days' data. Soil temperature without irrigation plot was always higher than that of irrigated plot, and soil tempterature of 10 litre/day irrigation plot was lower than that of 5 litre/day irrigation plot almost throughout daytime and at every measurement depth. The daily range of soil temperature in 10 litre/day irrigation plot was narrower than that in 5 litre/day irrigation plot. It is considered that these results are one of the reason of better growth in 10 litre/day irrigation plot.

Table 1. Tree height of *Acacia tortilis* (Samar) and *Prosopis spicigera* (Ghaff) in each treatment

Species	Irrigation amount (litre/day)	JUNE 1986 Height (SD) (cm)	JUNE 1987 Height (SD) (cm)	Annual growth (cm)
Acacia tortilis	5	85.5 (21.6)	88.1 (28.4)	2.6
	10	81.2 (15.1)	110.9 (41.3)	29.7
Prosopis spicigera	5	63.4 (7.2)	101.1 (18.1)	37.7
	10	67.0 (17.5)	141.2 (74.2)	74.2

Table 2. Daily maximum, daily minimum and daily range of soil temperature at different soil depth (July, 1986)

Depth (cm)	Max(°C)			Min(°C)			Range(°C)		
	cont[1]	5L[2]	10L[3]	cont	5L	10L	cont	5L	10L
5	50.1	44.0	41.2	35.1	29.5	30.4	15.0	14.5	10.8
10	45.4	42.8	38.1	39.8	32.2	31.7	5.6	10.6	6.4
20	40.4	39.8	39.4	39.5	34.7	33.6	0.9	5.1	5.8
30	40.0	38.4	37.4	39.7	36.8	36.2	0.3	1.6	1.2
50	39.4	38.3	36.9	38.7	38.0	36.5	0.7	0.3	0.4

NOTE : cont[1]; control plot (without irrigation)
5L[2] ; 5 litre/day irrigation plot
10L[3] ; 10 litre/day irrigation plot

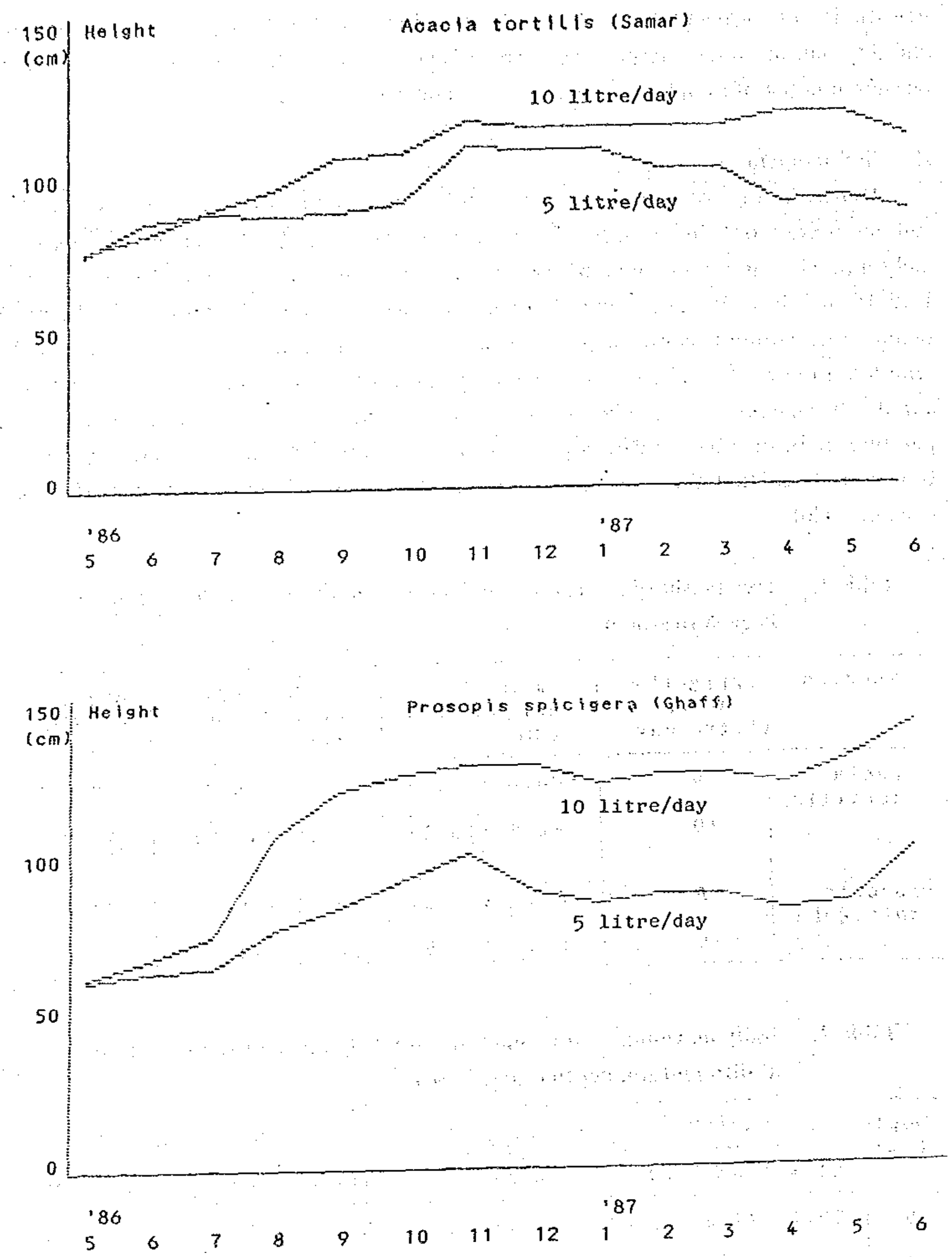
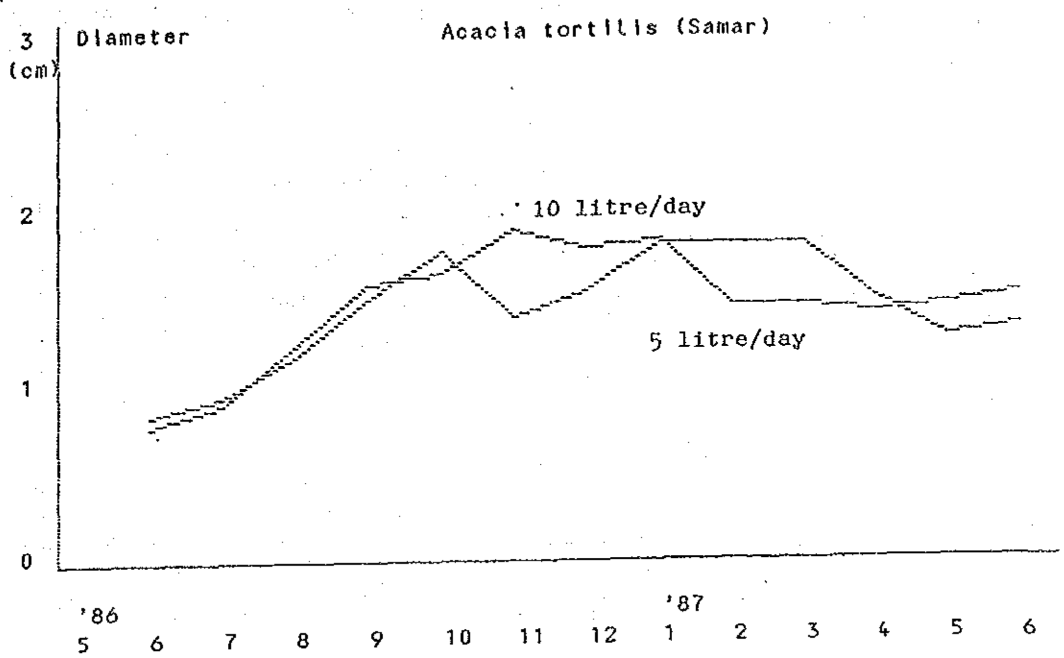


Fig. 1. Change in tree height of *Acacia tortilis* and *Prosopis spicigera*



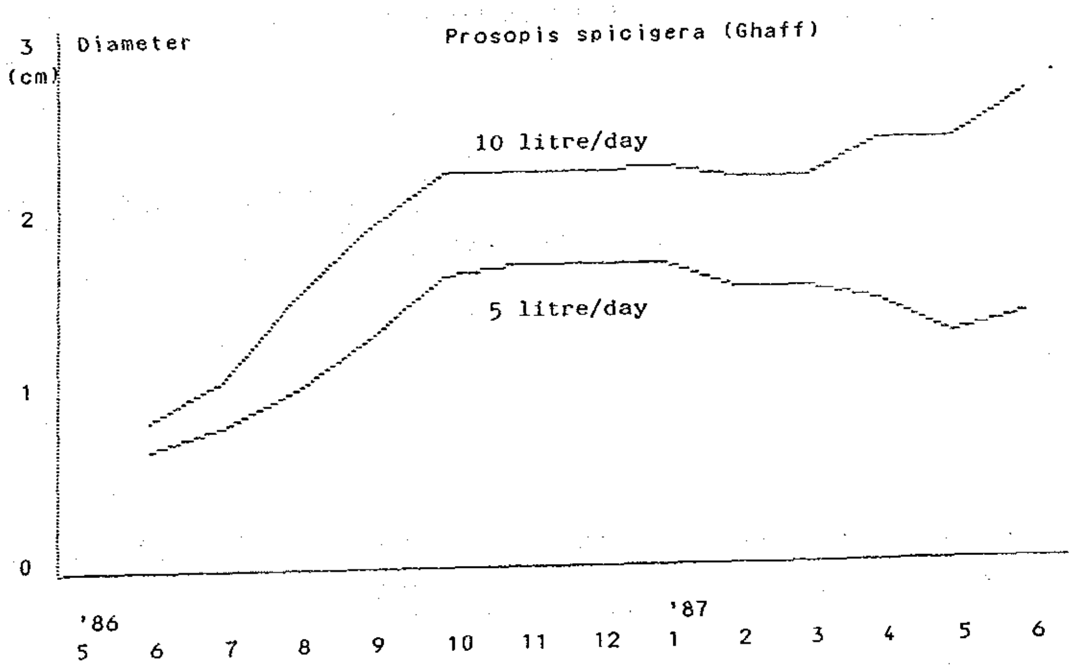


Fig. 2. Change in trunk diameter of *Acacia tortilis* and *Prosopis spicigera*

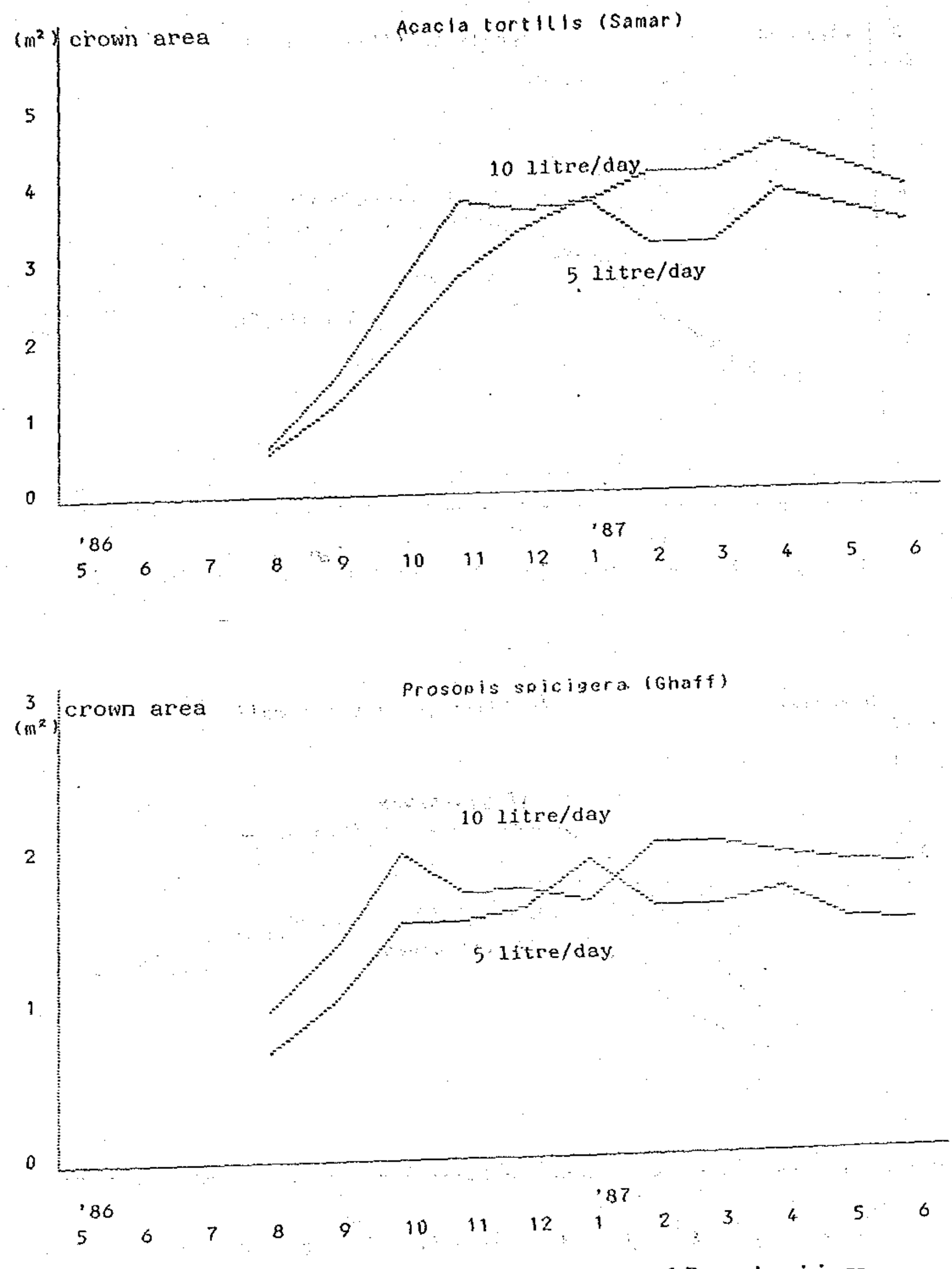


Fig. 3. Change in crown area of *Acacia tortilis* and *Prosopis spicigera*

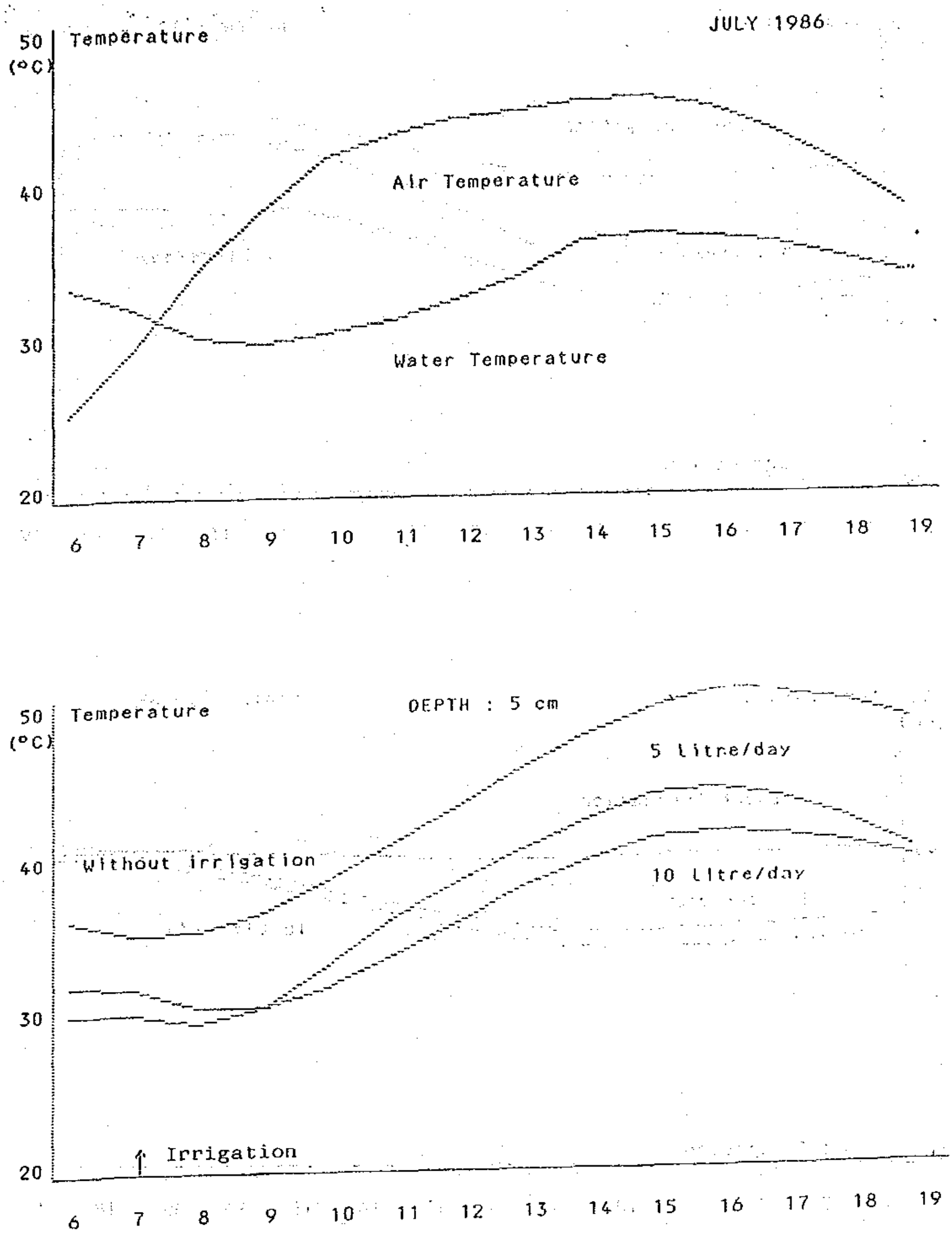
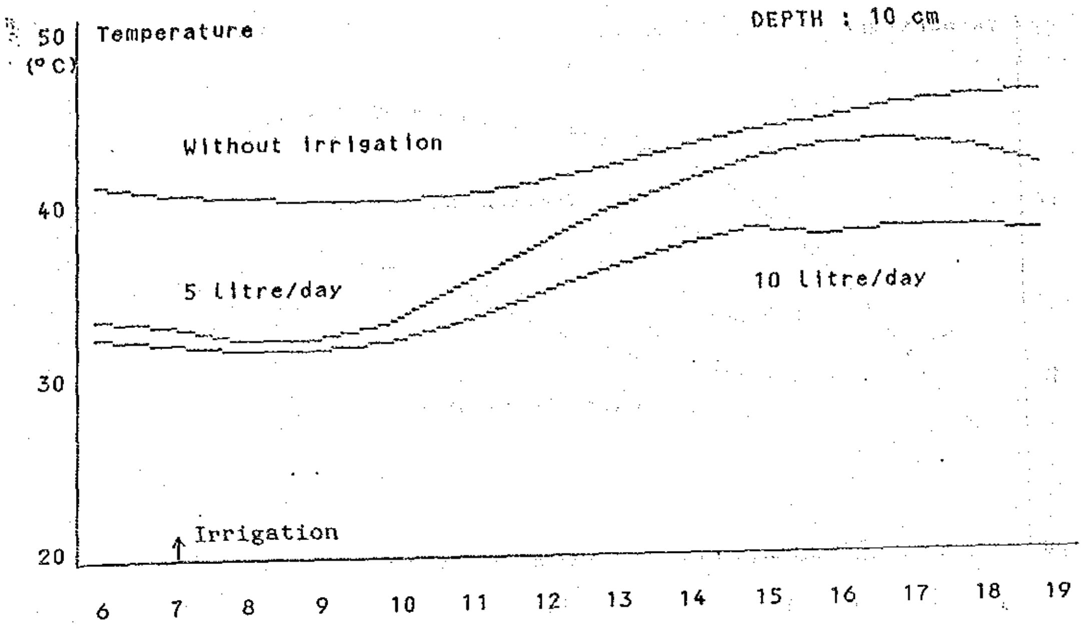


Fig. 4. Diurnal change of air temperature, water temperature and soil temperature at 5 cm depth



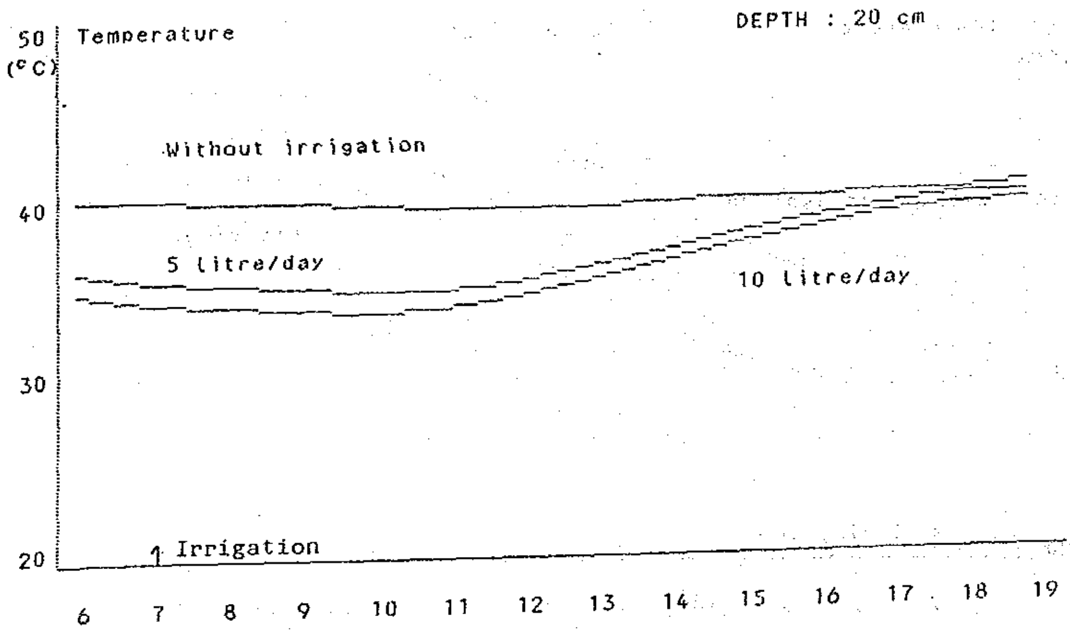
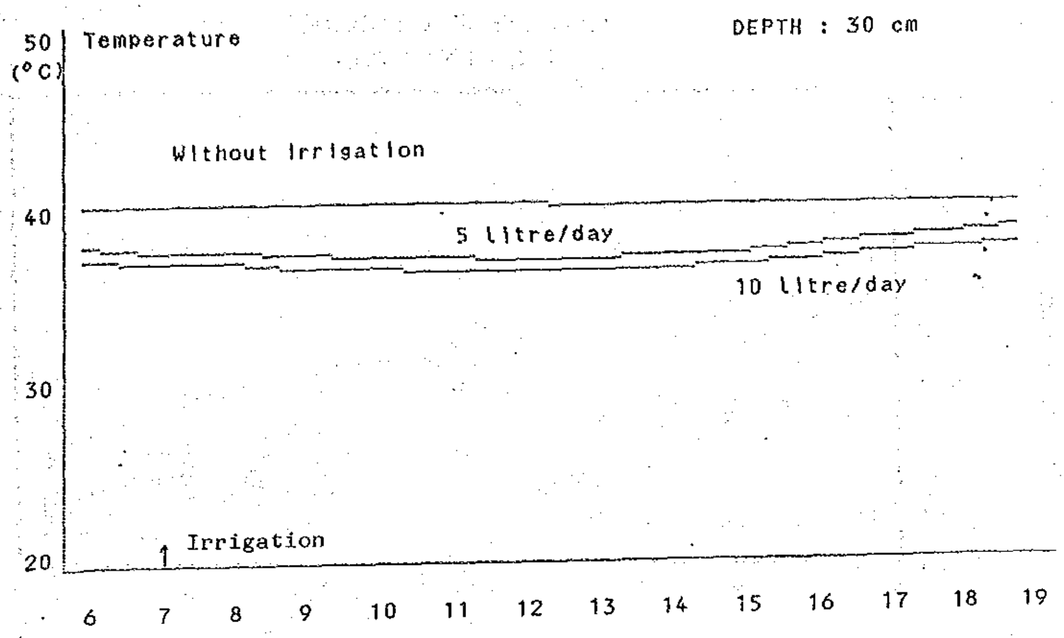


Fig. 5. **Diurnal change of soil temperature at 10 cm depth and 20 cm depth**



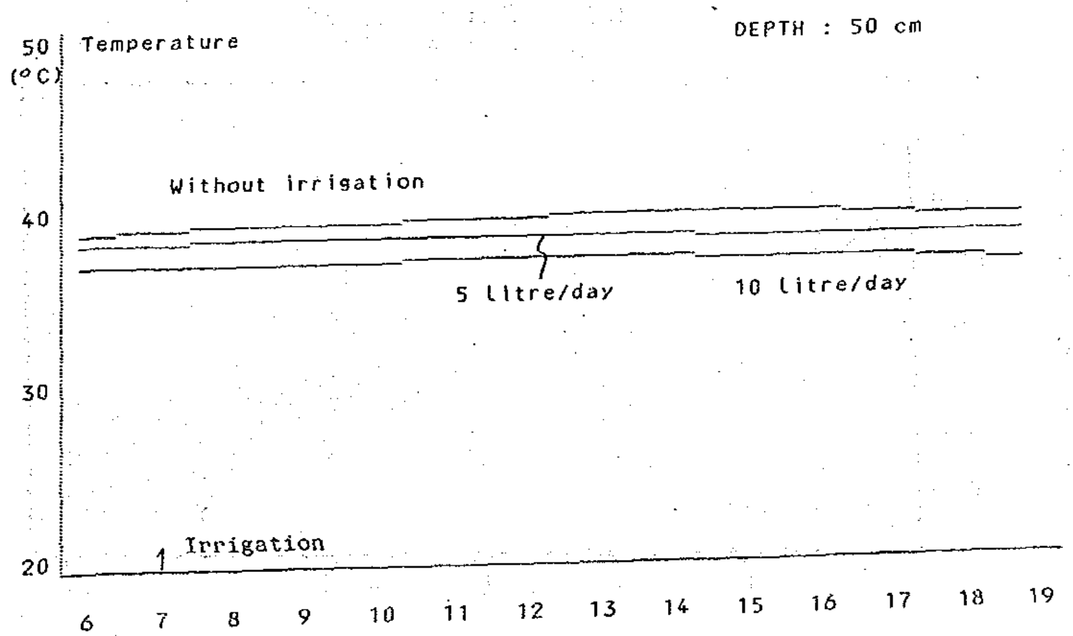
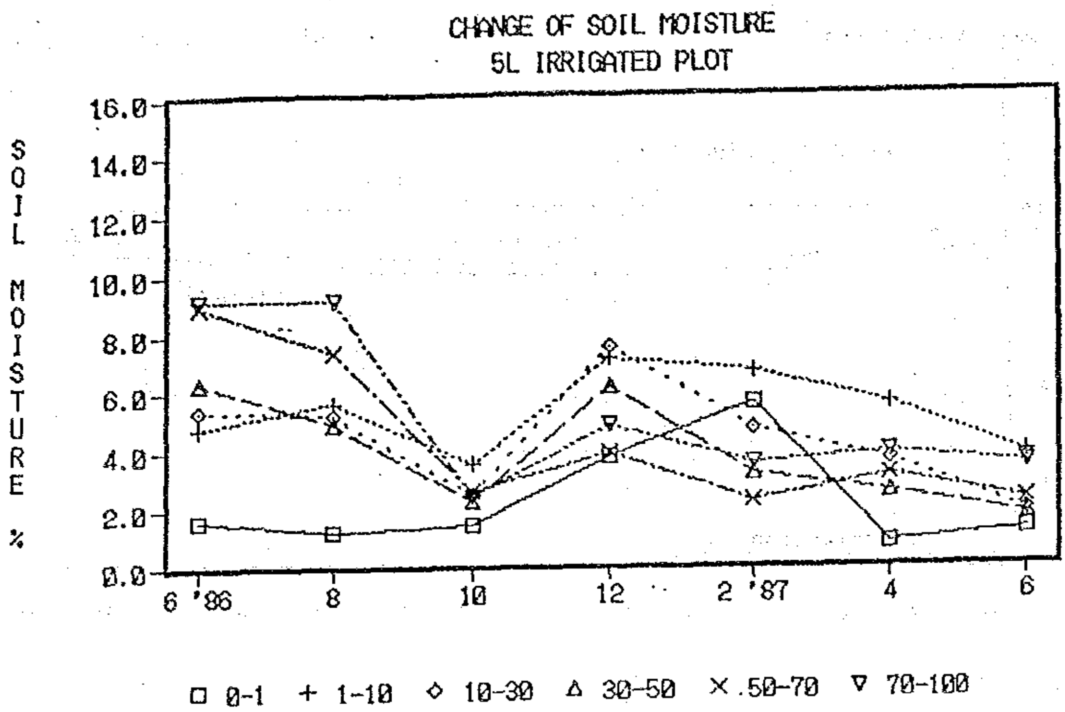


Fig. 6. **Diurnal change of soil temperature at 30 cm depth and 50 cm depth**



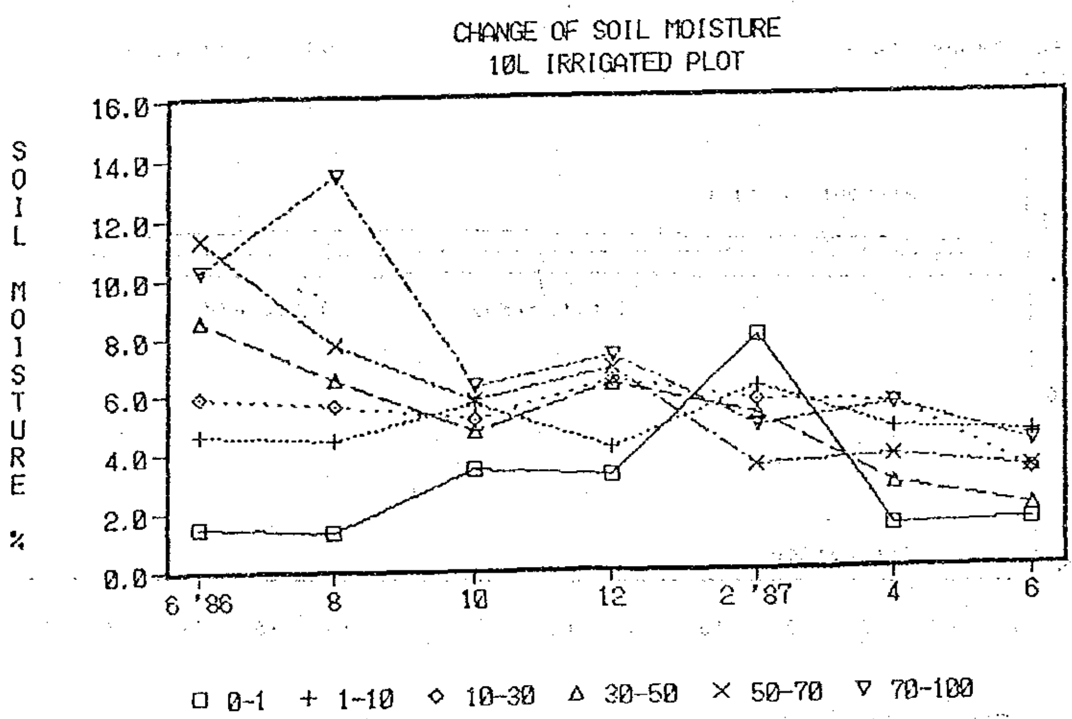


Fig. 7. Change in soil moisture of different soil layers

(7) Effects of Mulching on Wind Eorison of Sand

ABSTRACT

Effects of three kinds of materials on wind erosion were studied in the Experimental Farm of United Arab Emirates University, Faculty of Agriculture during 6 months period, starting from October 1986. Natural gravel of 1 and 2 cm thickness, synthetic resin emulsion of 5, 7.5 and 10% and asphalt emulsion of 2 and 3 L/m^2 were used of proved to be effective for sand fixation.

INTRODUCTION

Effects of three materials on wind erosion were studied to find their ability to fix sand, and to indicate the suitable amount of three materials to be used as mulching.

MATERIALS AND METHODS

Sand was collected from the sand dune near the Experimental Farm of UAE University and added to wooden boxes of 40 cm long, 40 cm wide and 10 cm deep. Three kinds of materials, natural gravel, asphalt emulsion, synthetic resin were used as mulching materials and applied on surface of each box. Each material were used in three levels with three replications. The natural gravels were placed on surface at 0.5, 1 and 2 cm thickness (7, 14 and 28 kg/m^2). The asphalt emulstion was sprayed on surface by a handy type sprayer at a rate of 1, 2 and 3 $liter/m^2$ while synthetic resin emulsion was diluted with water at a rate of 5, 7.5 and 10% (v/v) and sprayed similarly at a rate of 2 L/m^2. These boxes were left in the Experimental Farm. Erosion was determined by weighing the remained sand in the boxes and by observation of eroded area weekly. Eroded area was determined as follows: surface of the box was divided into 16 of 10 cm square, and erosion percentage for each square was estimated by eye measure, and results were shown as means of each square. Sand was added periodically in control plot.

Each box was divided into sixteen equal squares and we measured the erosion rate by judging the percentage of eroded area in each suqare every week. The weight of each box was measured to get the amount of blown sand every week. The results were shown as means of each square and sand was added periodically in control plot to replace the blown sand in Order to compare it with other plot.

RESULTS AND DISCUSSION

The amount of remaining sand is shown in Fig. 1. In the control plot, sands were eroded rapidly within 2 or 3 days after adding the sand. On the other hand, the natural gravel, asphalt emulsion and synthetic resin emulsion were remarkably affective in fixing sand compared with control plot. Among these treatments, natural gravel of 0.5 cm in thickness was eroded gradually and asphalt emulsion of 1 L/m^2 were eroded rapidly after

4 months from the beginning of treatment, and other plots were not eroded during the six months period. The degree of erodability in natural gravel of 0.5 cm thickness was low, and that in asphalt emulsion of 1L/m^2 was high.

The percentage of eroded area in each treatment is shown in Fig. 2. The tendency of erosion in control plots, synthetic emulsion and asphalt emulsion were similar.

The erosion of each plot after 6 months period is shown in Table 1. Eroded sand for plots of natural gravel of 0.5 cm in thickness and asphalt emulsion of 1 L/m^2 during 6 months period were 15kg/m^2 and 61 kg/m^2, respectively, this difference is due to the binding property of mulch moledules. After erosion, natural gravel still remained on the surface, but asphalt emulsion cracked and blown away by wind.

The results of this experiment indicates that natural gravel of 1 and 2 cm in thickness, synthetic resin emulsion of all levels, and asphalt emulsion of 2 and 3 L/m^2 were effective for sand.

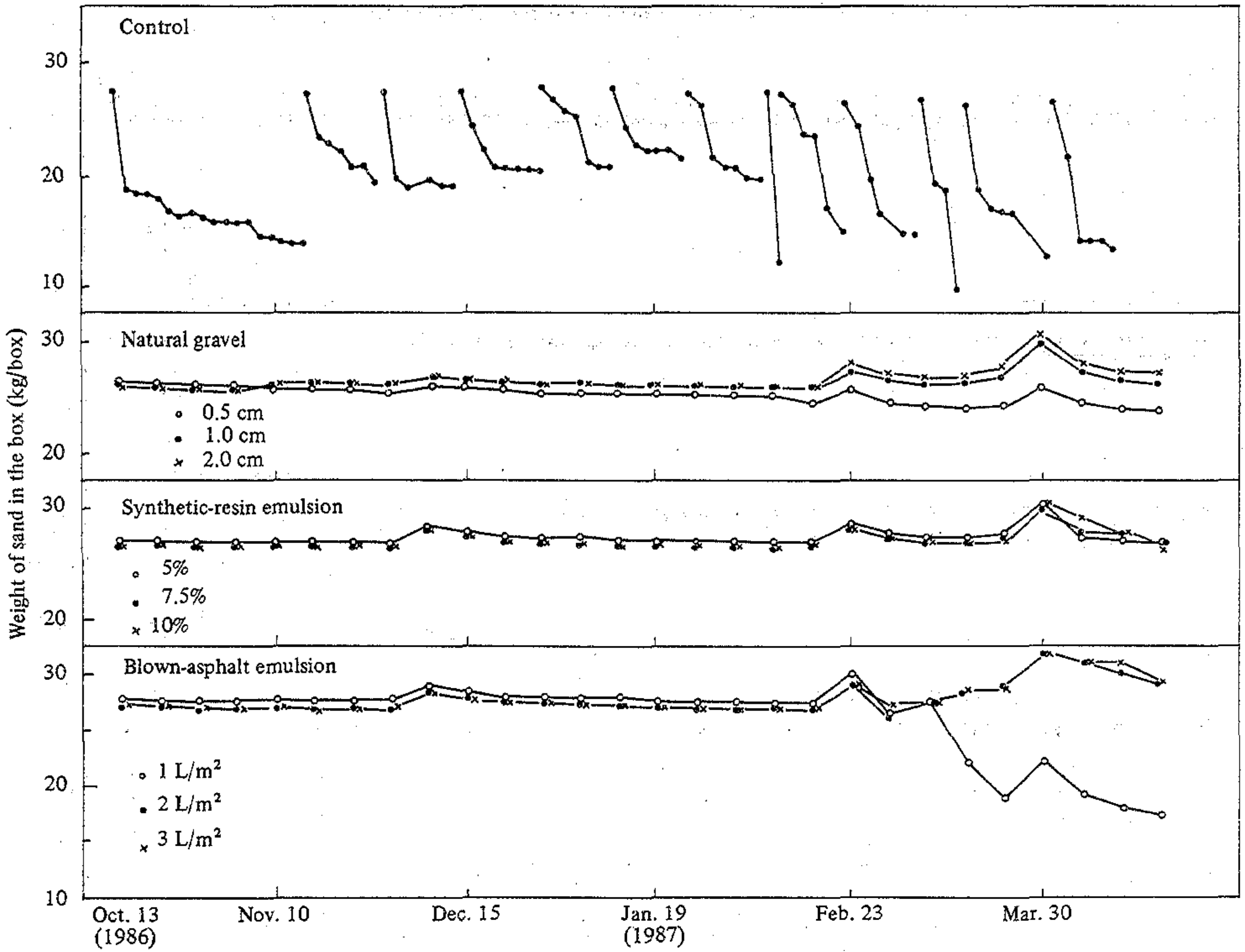


Fig. 1. Changes of erosion determined by weighing remained sand in the box

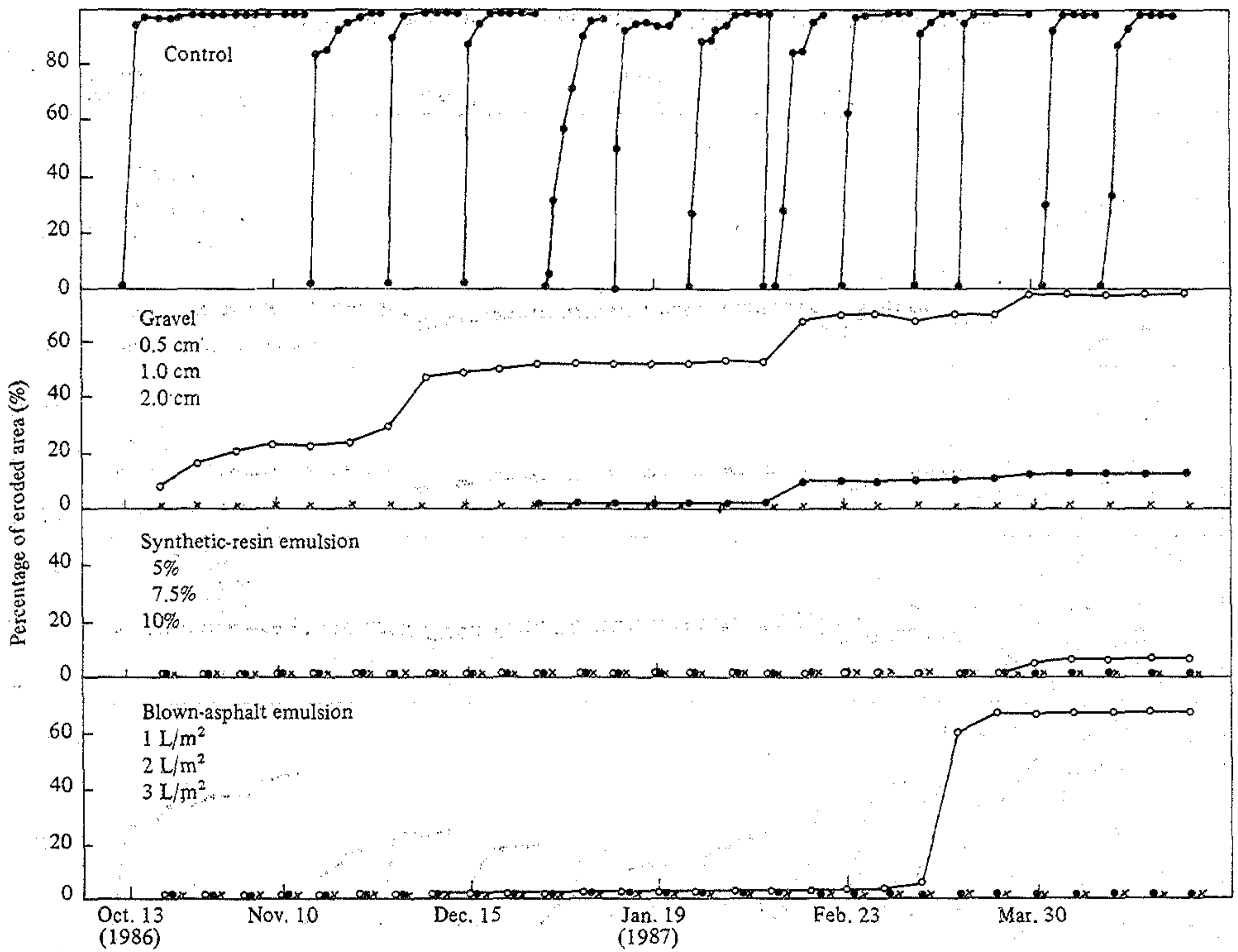


Fig. 2. Changes of eroded area percentage in each plot after treatment

Table 1. Erosion of each plot after 6 months as influenced by mulch treatments

Treatment		Eroded sand (kg/m^2)	Eroded area (%)
Natural gravel	0.5 cm	15	80
	1.0	0	13
	2.0	0	1
Synthetic resin emulsion	5 %	0	6
	7.5	0	0
	10	0	0
Blown asphalt emulsion	1 L/m^2	61	67
	2	0	0
	3	0	2

2. Theme B : Studies on the Improvement of Cultivation Methods for Crop Production under Irrigation of Saline Water

Theme B-1 : Studies on the Effect of a Subsurface Compost Layer on Water Preservation, Salinity and Yields of Crops in Sandy Soil

(1) Effect of Compost Layer in Subsurface Soil on the Yield of Alfalfa (*Medicago sativa* L.) Irrigated with Sweet Water

ABSTRACT

Thick layer application of bark compost in subsurface soil (T-treatment) increased the green matter yield of alfalfa compared to the two other treatments (whole layer application and control) under high and low irrigation levels. Alfalfa in T-treatment absorbed higher amounts of N, P, K, Ca, Mg and Na than the other two treatments under both irrigation levels.

INTRODUCTION

The main problem limiting agricultural production in arid lands (desert area) is the unavailability of irrigation water. And if irrigation is used, accumulation of salt on the soil surface will also be a problem because it imposes a stress on growing crops and may lead to low crop yield or a complete crop failure. Hence, saving irrigation water and reducing salt accumulation are very important objectives of arid land agriculture or dry land agriculture.

Therefore, the general objectives of the present study is to investigate the effect of compost layer in the subsurface soil on the yield of alfalfa under the conditions of UAE.

MATERIALS AND METHODS

This experiment was conducted at the Experimental Farm of UAE University in 1986/1987. The Farm soil is sandy and shallow. The experiment was laid out in a completely randomized design with three replications. The treatments were : Thick layer application in subsurface soil (T), Whole layer application (W) and Without application (C, Control) of organic matter. Thick and whole layer are forms of organic matter layers. The plot size was 20 m^2. The amount of organic matter added was 20 tons/ha. The compost layer in T-treatment was laid down the soil to a depth of 15 cm in form of sheets while the compost in W-treatment was mixed with the top layer of the soil.

Omani cultivar of alfalfa was sown on 16th December 1986 with a seed rate of 40 kg/ha and in rows 50 cm apart. The experimental area was fertilized with 250 kg/ha of compound fertilizer (18:18:5:1.5), 100 kg/ha of potassium sulfate and 150 kg/ha of triple superphosphate at sowing. Then the top dressing was applied after the first cut with 250 kg/ha of compound fertilizer (18:18:5:1.5) and after the 2nd cut with 150 kg/ha of the same compound fertilizer.

Each plot ws irrigated by drip system with 17 mm every day up to 20th January. Treatment of different levels of irrigation was initiated from 1st April. Plots in low and high irrigation levels were irrigated with 15 mm every four or two days, respectively. After 19th April, 10 and 15 mm/day were respectively applied for low and high irrigation levels.

Fresh weight of alfalfa was measured during all harvests. Nitrogen in alfalfa samples were determined with Kjeldhal method. Phosphorus in alfalfa samples was determined with colorimetric method by chlorostannous acid in hydrochloric acid after ashing the samples. Potassium, calcium, magnesium and sodium after ashing the samples were determined with atomic absorption spectrophotometer.

Soil samples were collected from different depths (0–1, 1–13, 13–25, 25–30, 30–40 cm from the soil surface) of each plot. The moisture contents of the samples were measured. EC, pH and soluble cations, anions in saturation extracts of soil samples were determined. EC and pH were measured with electrical conductivity meter and glass-electrode 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 sulfuric acid. Sodium and potassium were determined with flamephotometer. Sulfate was measured with turbidity of barium sulfate.

RESULTS AND DISCUSSION

Fresh matter yields of alfalfa were significantly increased under both high and low irrigation levels in T-treatment during all harvests (Fig. 1). In general differences in yield of alfalfa among treatments were significant under both levels of irrigation. Differences between the W-treatment and the control were not significant. The increases in yield of the T-treatment over the control were 44% and 52% under low and high irrigation lelves across four harvests.

Fig. 2 shows the amount of mineral elements absorbed by alfalfa tops. In T-treatment, generally, alfalfa absorbed higher amount of N, P, K, Ca, Mg and Na than the other two treatments under both irrigation levels. And the uptake of Na and K was comparatively higher than the other elements.

The moisture contents of compost layers in T-treatment were significantly higher than those of the equivalent layers in the other two treatments under both irrigation levels (Fig. 3).

The pH values of saturation extract are shown in Fig. 4. There were no major differences of pH values among the treatments even under different irrigation levels. However, the pH values of the compost layers in T-treatment were lower than the other soil layers. This would be due to elution of humic and fulvic acids from the compost.

The EC values of saturation extract are shown in Fig. 5 High EC values at the soil surface were observed for all the treatments under both irrigation levels at the 4th harvest. Relatively high EC values were also observed in the compost layer of T-treatment under both irrigation levels at the 1st and 4th harvest. However, high irrigation showed a tendency to decrease the EC value in the compost layer by leaching the mineral elements to the lower layer with irrigation water.

Cation and anion contents in saturation extract are shown in Figs. 6 to 9. Cations except K and anions except carbonate, specially Na and Cl, accumulated in the compost layer of T-treatment compared with those in the equivalent layers of the other two treatments. However, accumulation rates of these elements were lower in high irrigation level than in low level. The elements such as Na, Mg, Ca and Cl were accumulated at the soil surface in all the treatment under both irrigation levels at the 4th harvest.

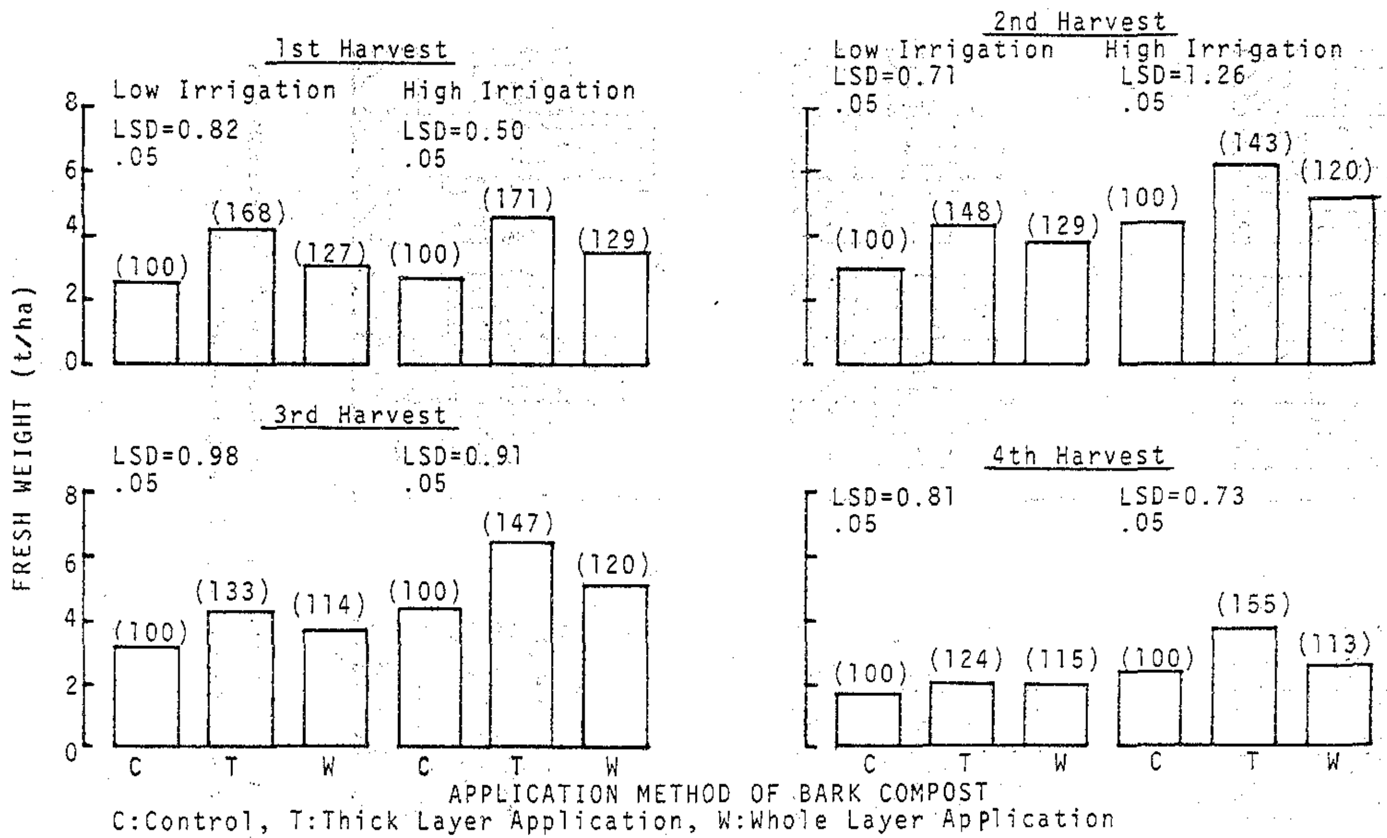


Fig. 1. **Relationships between fresh weights of alfalfa and application methods of bark compost under irrigation of sweet water**

Figures in parentheses are indexes for 100 of control

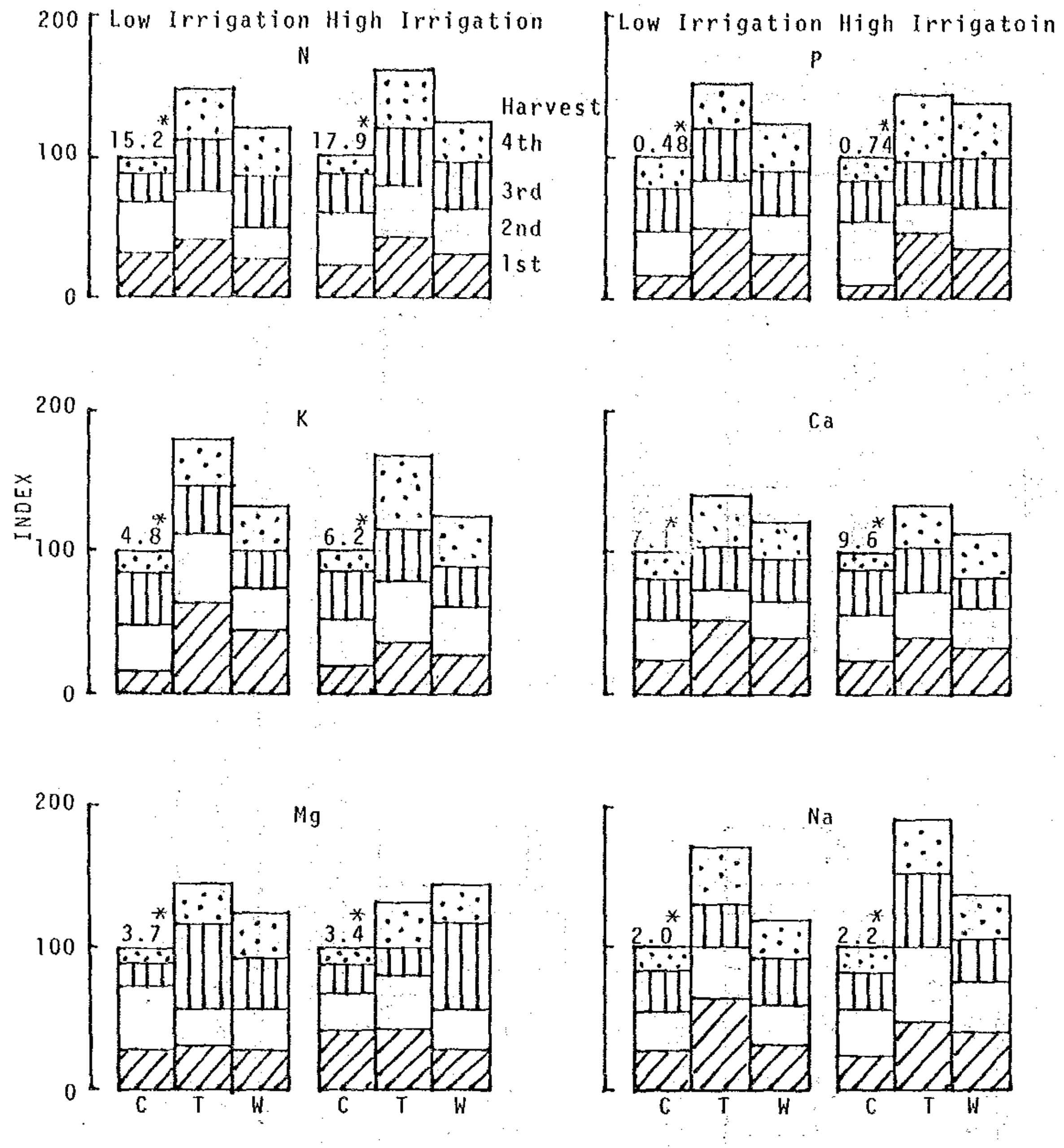


Fig. 2. **Increase in uptake of mineral elements by alfalfa tops with different kinds of application methods of bark compost in comparison with control**

*** Kmol/ha**

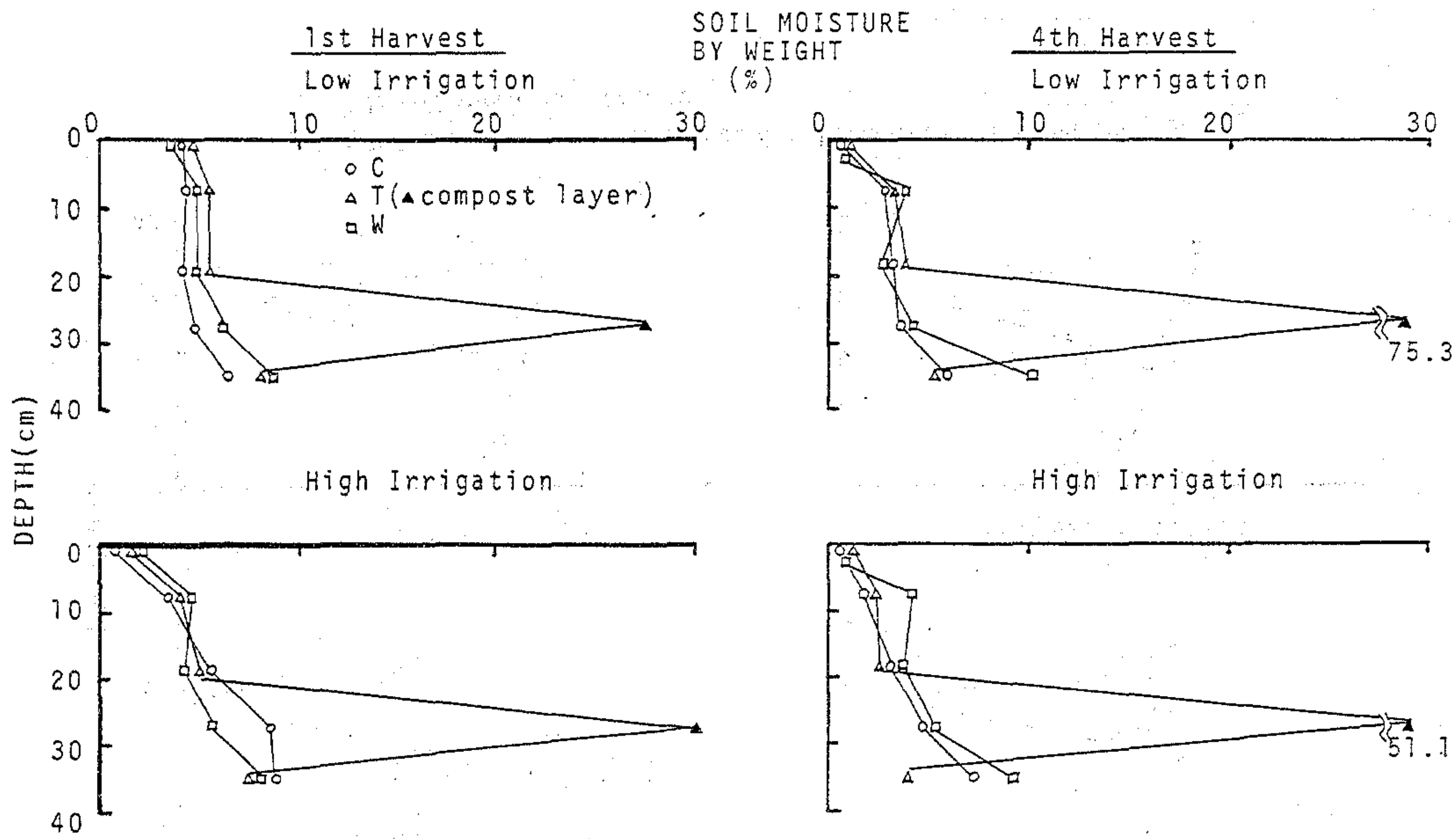


Fig. 3. Soil moistures in different depths from surface at each harvest as a function of application methods of bark compost and amounts of irrigation