# EXPERIMENTS ON THE INCREASE OF WATER-HOLDING CAPACITY IN SANDY SOILS

Chang-Chi Cheng[1], Ming-Young Jan[2], Hsiao-Jen Huang[3], Chun-E Kan[4]

**ABSTRACT**

There are sandy soils in the western coastal agricultural area in Taiwan. Hence, how to increase the water-holding capacity has been one major issue in that area. The objective of the study is to conduct a series of experiments by various treatments of the soils, as well as various irrigation schemes, in order to improve the water-holding capacity in sandy lands.

The concept of lysimeters is applied in this study for the observation of outflow curves in order to better understand the variation of water-holding capacity. The lysimeters used in the experiments were designed and simulated by plastic buckets with 50 cm in top opening diameter, 40 cm in bottom diameter, and 80 cm in height. 30 liters of water was irrigated without disturbing surface soil while water depth not exceeding 1 cm each time, and the curves of accumulated outflow vs. time were observed and recorded. Five groups of experimentation were prepared, they are, 1)Experimental Station Group, where the sandy soil from local area was used, 2)Reservoir Sludge Group, where the sedimentation from a local reservoir (Shih-Men) was used, 3)Single-layered AX-xxxb Group, where the bio-degradable polymer was placed at 40-cm depth, 4)Mixed-AX-xxxb Group, where the polymer was mixed with local soil, and 5)Mixed-Reservoir-Sludge Group, where the sedimentation from A-Kung-Tien Reservoir was mixed with local soil.

Basically, the shifting trends of the accumulation outflow curves in each set of experiments could be reasonably explained. Among all tests, Group 3 of Single-layered AX-xxxb at the depth of 40-cm depth to simulate the hard-pan in field has reached most acceptable result. However, how to place material at the certain depth in field is another issue.

Keywords: sand, water-retention capacity, lysimeter

---

[1] Associate Professor, Department of Industrial Engineering and Management, Ching-Yun University, #229, Chien-Hsing Road, Chung-Li, Tao-Yuan, TAIWAN, phone: 886-3-4581196 ext. 6117, fax: 886-3-4683298, e-mail: faber@cyu.edu.tw

[2] Associate Professor, Department of Civil Engineering, I-Shou University, Kaoshiung, TAIWAN, phone: 886-910-871580, myjan@isu.edu.tw

[3] Senior Engineer, Chi-Ting Experimental Station for Upland-Crop Irrigation, Water Resources Planning Institute, Water Resources Agency, Taiwan, hsj@wrap.gov.tw

[4] Emeritus Professor, Department of Bio-Environmental Systems Engineering, National Taiwan University, Taipei, TAIWAN, phone: 886-2-27023635

## I. FOREWORD

There're mostly sandy lands in western Taiwan, and the increase of water-holding capacity in sandy lands has become the major issue of this area. The increase of water-holding capacity can be reached by changing the distribution structure of soil particles. The use of infiltration by gravity through irrigation water is further introduced to gradually alter the soil structure, and the water-holding capacity of sandy soil is hence expected to be raised. The concept of lysimeters is applied in this study when water with various clay or silt content is irrigated to sandy lands, and the outflow is observed to better understand the variation of water-holding capacities.

Desertification has been a global issue. Statistical figures of United Nations indicate that over 100 countries and 900 million people worldwide are currently affected by desertification. Characteristics of desertification include low land surface coverage as well as low precipitation, and especially the low water-retention ability has become one major problem in water-shortage areas.

Due to the improvement of irrigation techniques, sandy lands are no longer considered as poor lands. Yet, the inherited shortcomings of low water-retention capacity have still made them incomparable with conventional good lands. As a result, under the conditions of low water-retention capacity, it is the intention of the study to conduct experiments on the increase of water-retention capacity of sands. And the Chi-Ting Experimental Station is selected for the related experiments.

## II. EXPERIMENT LAYOUT

1. Basic data

The basic data for the soil characteristics in the experimental site, e.g., specific gravity, bulk specific gravity, void ratio, saturation water content, soil texture, and infiltration coefficients, etc, are shown in Table 1.

**Table 1** Physical properties of the soil in Chi-Ting Experimental Station

| Sieve Analysis | | | Soil texture | Organic content(%) | PH value | Remarks |
|---|---|---|---|---|---|---|
| sand(%) | clay(%) | silt(%) | | | | |
| 95.32 | 2.50 | 2.18 | sand | 1.66 | 5.87 | |
| Specific gravity | Bulk specific gravity | porosity(%) | Void ratio | Saturation water content(%) | Wilting coefficient | |
| 2.63 | 1.47 | 44.12 | 0.79 | 29.71 | 1.37 | |

2. Design of lysimeters

The experiments were conducted in Chi-Ting Experiment Station. The lysimeters were simulated by five specially-made acrylic rectangular container with 50 cm x 50 cm in length and width, and 70 cm in height. A hole was first drilled at the bottom for drainage as well as measurement, followed by installing a drainage pipe, and filling with 2 cm gravels. An layer of un-woven fabric was placed before the sand from experiment area was put on top, as shown in Figure 1.

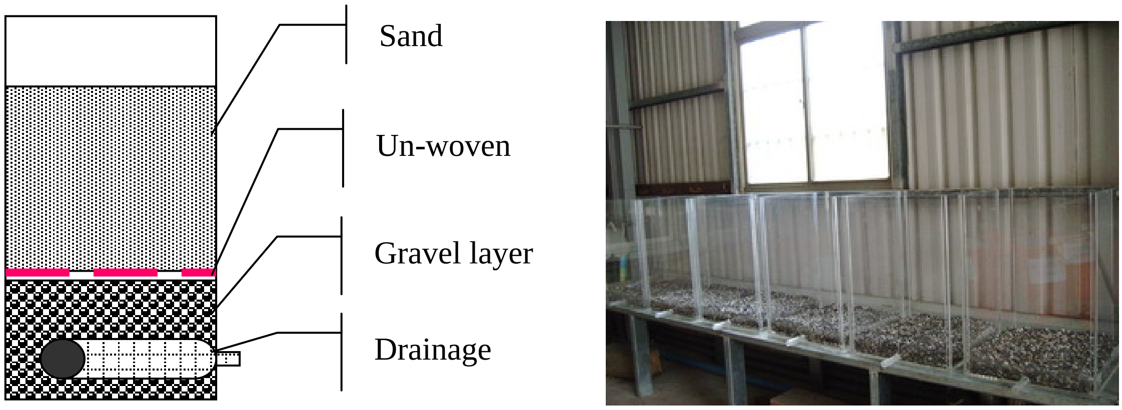



**Figure 1** Design of lysimeter

3. Sludge content in the irrigation water

The sludge samples from A-Kung-Tien Reservoir and Shih-Men Reservoir were used as the source for mixing in irrigation water. The sludge was first dried, pounded, and then sieved, before being uniformly mixed in the irrigation water. A control experiment of plain water was also prepared.

4. Irrigation plan

It was expected that the voids could be filled with irrigation water, thus a volume of 50 liters was needed for each irrigation practice. Basic principles for the irrigation practice were that the surface soil was un-interrupted, the depth for surface water was under 1 cm, and the sprayer was used for irrigation. The irrigation frequency is based on the water content in the soil, especially the field capacity. And after real operation, one-week was determined as the irrigation period in the beginning, and in the following stages, irrigation was applied according to the degree of cracking after the soil surface was dried.

5. Observation and Recording

A stop watch was used to record the discharge time in each irrigation practice, the measurement of record interval as well as the amount of water were adjusted according to discharge condition, and the discharge-time curve was plotted. In addition, an electronic weighting scale connecting to a notebook computer was used in the data collection, and the accumulated discharge-time data were automatically recorded.

## III. EXPERIMENTAL RESULTS AND ANALYSIS

As this was a follow-up study, five groups of experiments were conducted by using the newly-designed transparent acrylic lysimeters. These five groups were:

1. Field Control Group: the local sandy soil was used.
2. Shih-Men Group: the sludge from Shih-Men Reservoir was mixed in the plain water

and irrigated on local sandy soil,

3. Single-layered AX-xxxb Group: a layer of 100g of AX-xxxb was placed in the depth of 40 cm to simulate the hard-pan in paddy fields,
4. Mixed AX-xxxb Group: 100g of AX-xxxb was mixed uniformly in the experimental soils, and
5. A-Kung-Tien Group: the sludge from A-Kung-Tien Reservoir was dried, pounded, and sieved, before being uniformly mixed with the experimental sands with the ratio of 1 to 5 by weight.

The preparation and the process of the experiments are shown in figure 2, and the results are described as well as analyzed as follows.

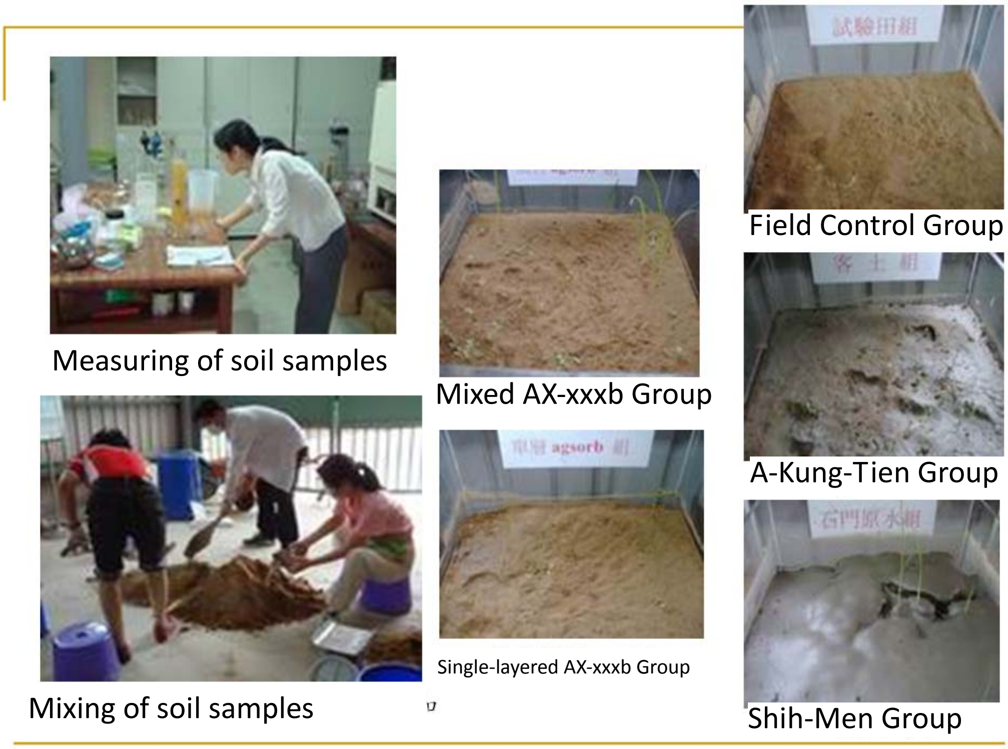



**Figure 2** Preparation of the experiments

1. Field Control Group

The plain water was irrigated in the lysimeter filled with local sand from the experimental site. Irrigation was applied in the period of one-week, or when the amount of discharge was small enough, and was continued until the accumulated discharge vs. time curves had reached stable, as shown in Figure 3.

Overall speaking, except in the first application of irrigation in which there was detention effect due to the considerable void volume in the soil particles, there were lag time before discharge, and the discharge volume had reached stable in later experiments. There is significant difference in the accumulated discharge curves between the first application of irrigation and later observations. In the first application, the irrigation water is retained to fill the voids between soil particles. Theoretically, the amount of retained water should be close to the field water content of the experimental soil.

From observations on the later accumulated discharge curves, it is found that there is a moving trend to the left-upper direction, as shown by the arrow in Figure 3. This phenomenon is the same as the Plain Water Group of the previous study where all curves follow almost at the same track, and it indicates that a stable condition is reached in considerably short time by using plain water for irrigation.

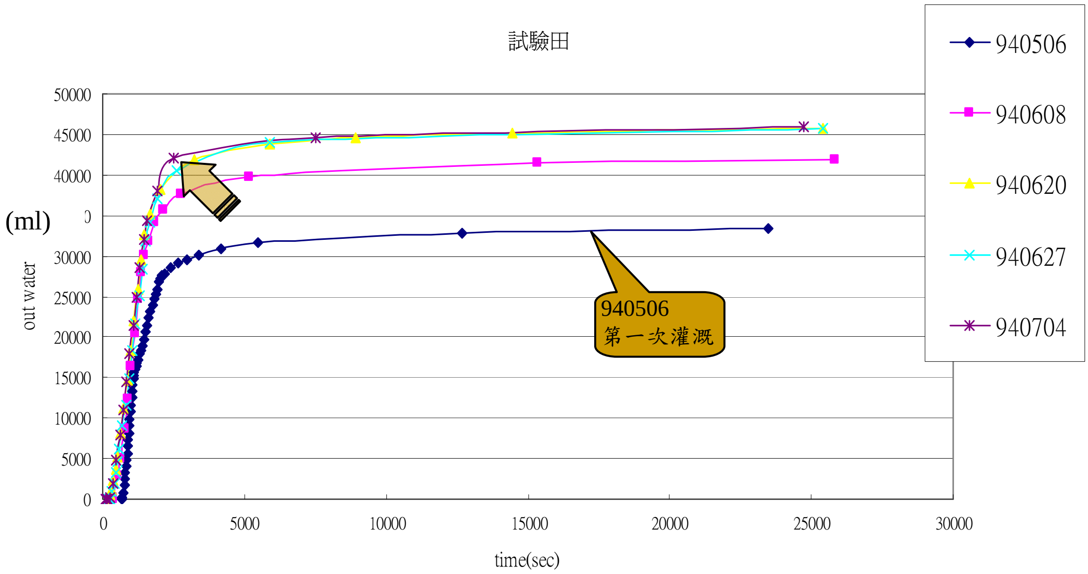



**Figure 3** Accumulated Discharge for Field Control Group

2. Shih-Men Group

When the first irrigation was applied in this Group, 50 liters of the original water from Shih-Men Reservoir with sedimentation sludge was used. However, cracking occurred in the experiment sand layer when irrigation was first applied, and all sludge-contained irrigation focused at specific cracked spot, which led to the expansion of cracking spot, and a very thick concentration out-flow discharge was observed, as shown in Figure 4. The outflow discharge became clear only when the cracking was blocked by sludge. The explanation for this is that, the soil particles re-organized when the water with sludge flowed through, and extra space was released. Meanwhile, due to the high concentration of sludge in the irrigation water, the van der Waals force was stronger to keep the surface in shape. But cracking occurred when the force failed to withhold gravity, and the cracking extended when irrigation water concentrated to the cracked surface(Figure 5).

3. Single-layered AX-xxxb Group,

From the discharge-time curves of the results of Single-layered Group in Figure 6, it could be observed that except during the first application of irrigation, there was 10-liter more of irrigated water being retained owing to the effects of AX-xxxb as compared with the Field Control Group, other applications of irrigation were pretty much the same. It was almost confirmed that there was 100 times of water-holding capability (I.e., 10,000g of water could be retained by 100g of AX-xxxb) when the AX-xxxb was mixed with sandy soils. In addition, it was expected to have even better water-holding capacity if the irrigation interval between first and second application of irrigation could be shortened.

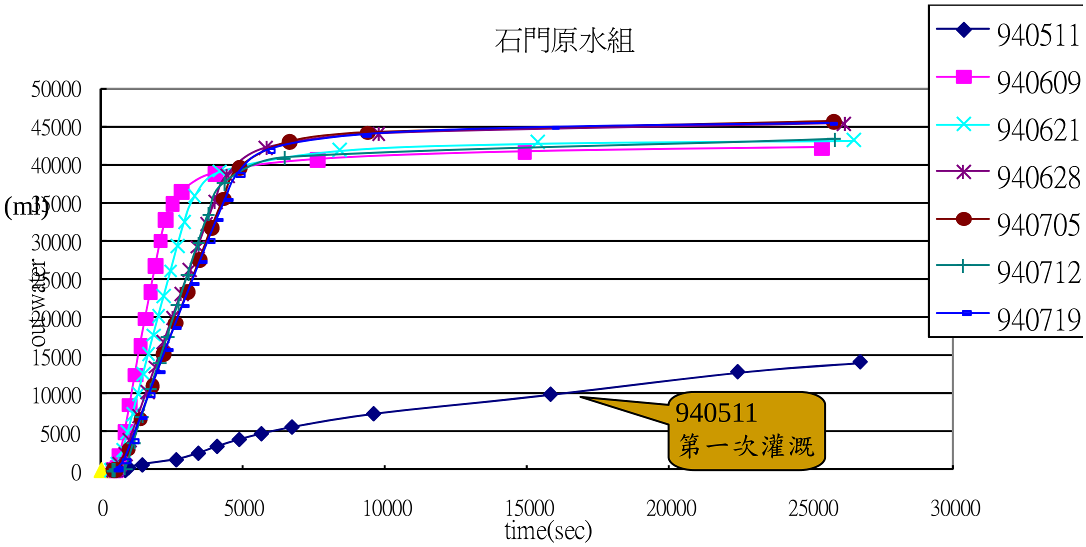
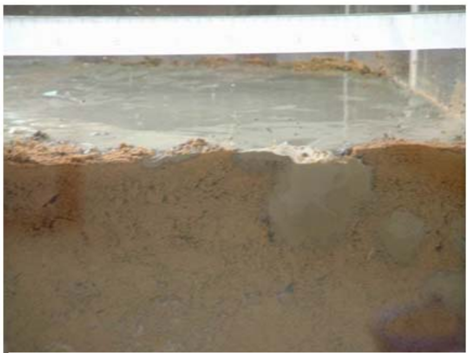



**Figure 4** Accumulated Discharge for Shih-Men Group



Surface cracking when irrigation is applied (side view)

Surface cracking when irrigation is applied (top view)

Gradual expansion of Surface cracking

High concentration of sludge in the outflow at the beginning

**Figure 5** Formation of cracked surface in Shih-Men Group

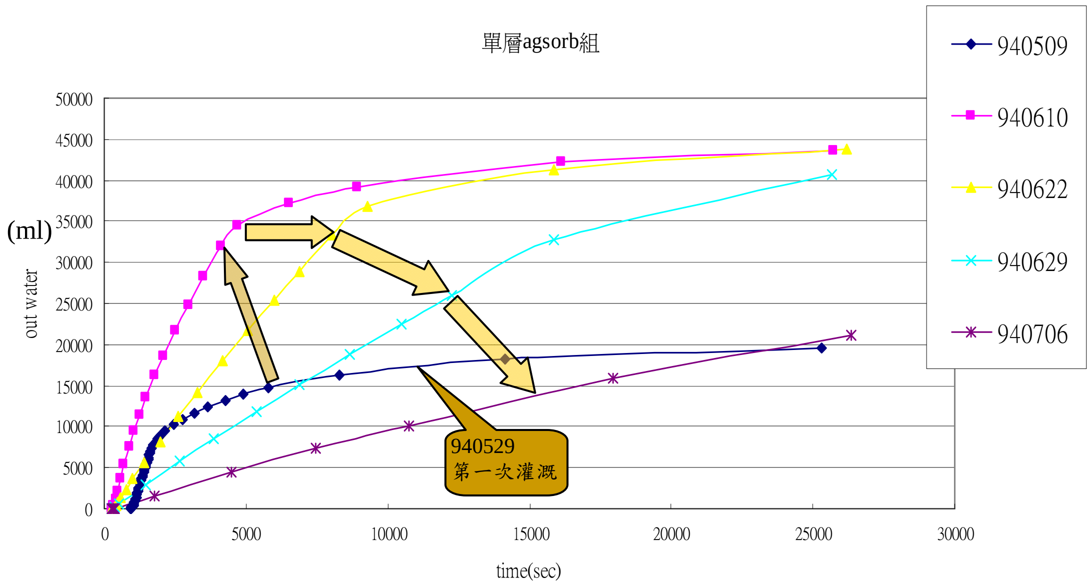



**Figure 6** Accumulated Discharge for Single-layer Group

4. Mixed AX-xxxb Group

The discharge-time curves of Mixed AX-xxxb Group were shown in Figure 7.

When the accumulated discharge curves of this Group in Figure 7 were compared with those of Single-layer in Figure 6, some interesting phenomena could be observed:

(1)There is a superb water-holding ability of AX-xxxb.

(2)When the hard-pan is simulated by the single-layered AX-xxxb, the results were surprising. The curve at the beginning was similar to the Plain Water Group. But when AX-xxxb had absorbed enough water, and had reached bonding effect, the later part pf discharge curves almost stayed at the track of one single line, which was very similar to normal paddy fields.

(3)From the aspect of water-holding ability, the single-layered group was far better than the mixed group. However, when the practical application to the field is concerned, how to put the AX-xxxb in place is one major issue.

5. A-Kung-Tien Group

The discharge-time curves of A-Kung-Tien Group were shown in Figure 8.

According to the curves in Figure 8, it could be observed that during the first application of irrigation, the lag time for outflow discharge was delayed for nearly one hour, while the amount of accumulated outflow discharge was obviously less than those in other groups. The explanation for it was that the sludge from A-Kung-Tien Reservoir had been ovened as well as pounded to powder before being imported to the lysimeter, and the water content was nearly 0. Instead, the soils in other groups were only air-dried, and was still containing certain amount of moisture. As a result, there was more space in this Group for absorbing more water during the first application of irrigation. And the following applications had longer outflow time, and slower discharge speeds, which indicated the remarkable improvement of water-holding capacity.

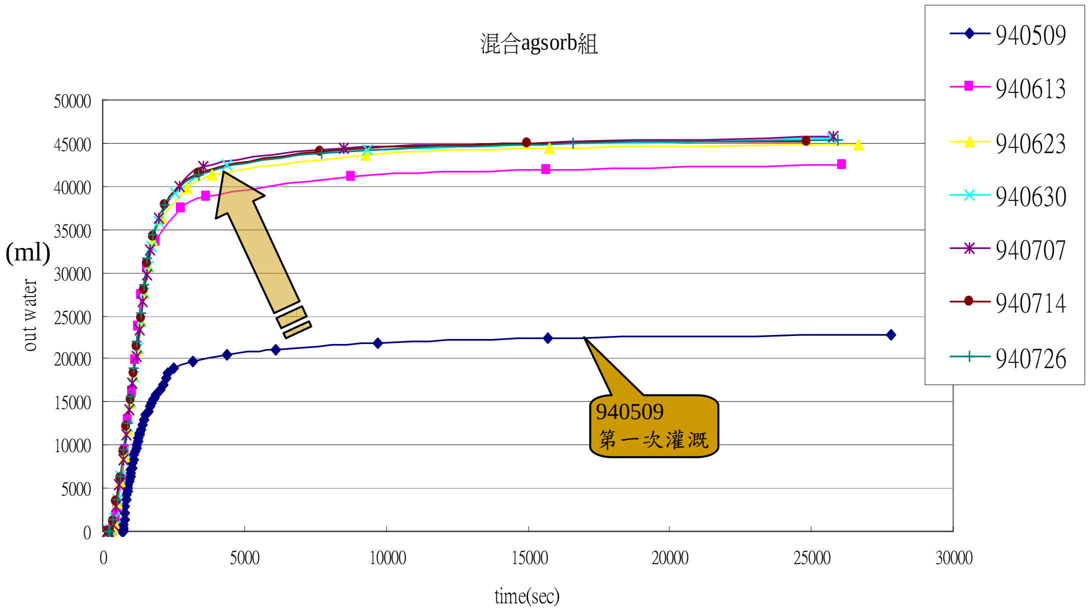



**Figure 7** Accumulated Discharge for Mixed AX-xxxb Group

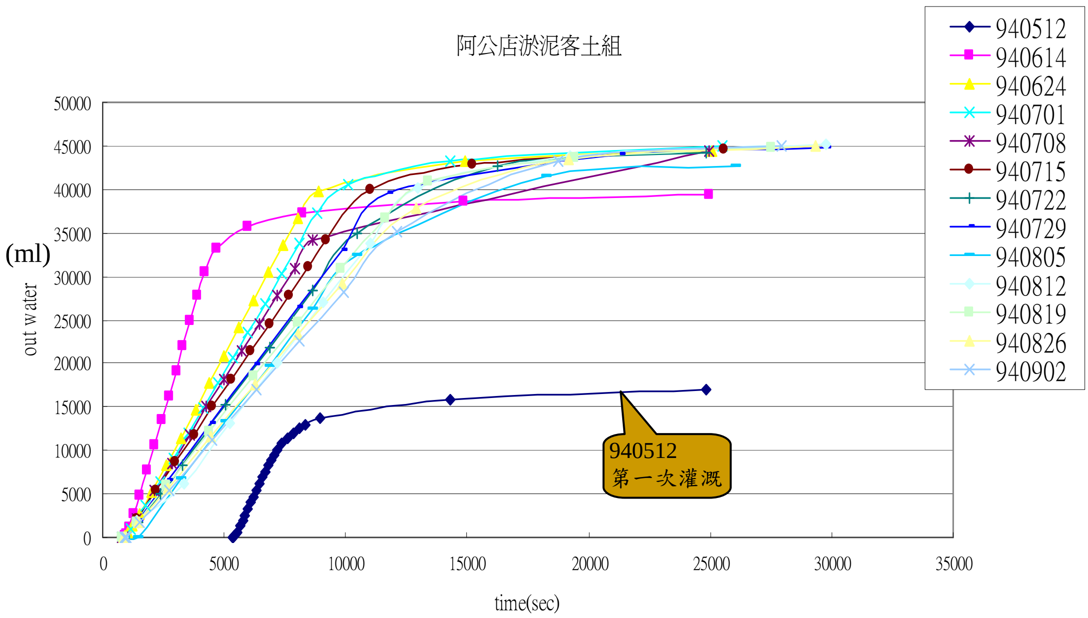



**Figure 8** Accumulated Discharge for A-Kung-Tien Group

## IV. CONCLUSIONS AND DISCUSSIONS

1. The objective of the study with series of experiments is in an attempt to improvement the water-holding capacity on sandy soils.
2. Importing soils from outside is one of the major ways to improve the soil water-holding capacity. However, the shortcomings of high cost and probable impacts on the environment have made it difficult to promote at this moment.
3. The five alternatives of experiments adopted in this study are all able to improve the water-holding capacity of sandy soils. The rankings in terms of water-holding capabilities are: Single-layered AX-xxxb＞A-Kung-Tien Group＞Shih-Men Group＞Mixed AX-xxxb＞Field Control Group, and there are significant difference between the first two groups.
4. The AX-xxxb samples adopted in this study is a polymer product from corn, and was developed to relieve the excessive harvest of corns. The benefits of this polymer product include a high water absorbing ability of 300 times by volume, and more importantly, being bio-decayable in 3-4 years.
5. The soil samples from various depth layers were taken before and after the experiments, and soil texture analyses were conducted. However, there were no evident changing trends could be observed from the data obtained. Explanations for this could be:
   (1)There were indeed no obvious changes.
   (2)There were sampling errors.
   (3)The accuracy of the experiments and analyses had not been met.
6. It is suggested that experiments of using various media materials to increase the water-holding capacity should be continued, and further experiments of crop plantation to better understand the effects of the alternatives on crop growth should be followed-up.

## REFERENCE


1. Cheng, Chang-Chi, Wei-Taw Lin, Yu-Chuan Chang, and Chun-E Kan, 2009. Study on the Increase of Water-Holding Capacity in Sandy Soils. 60th IEC Meeting and 5th Asian Regional Conference, 6-11 December 2009, New Delhi.