INVESTIGATION OF CROP PRODUCTION IN STABILIZED SAND DUNE USING AMB LAYER ASSOCIATE WITH DRIP IRRIGATION SYSTEM

Hassan Rouhipour
Faculty of Agriculture, Science and Research Campus Islamic-Azad University, Tehan. Iran.(Email: rohi@rifr-ac.ir).

ABSTRACT

Sand dune stabilization programmes in Iran has been highly successful. A considerable portion of the active dunes in the study area has already been stabilized ,and a good cover of annual and perennial species has been established. Here again this very successful program of sand dune fixation has raised another problem, once the protection is ensured, how to economically use this land. Three main possibilities may be considered: 1-production of firewood, wood and paper 2-production of pasture and animal products. 3-production of agricultural crops. Production of firewood does not appear to be an economically viable option in Iran. Light grazing has been proposed as a way of utilizing the stabilized areas of the dunes for food production. However, the delicate balance of dune system could be disrupted very easily. Thus in order to utilize the stabilized sand dune systems more efficiently, some high value crop or cash crops production is another alternative, where irrigation water is available. Dunes are equally suitable for growing cash crops but their fertility and high permeability appears to be a limiting factor. Thus to carry out this experiment AMB[1] layers were spread in two different depth, namely 45 and 60 Centimeters using AMB machine. Several cash crops such as watermelons, melons, cucumbers and tomatoes were planted and irrigation treatments were set up. This experiment indicated spectacular results in the production of Charleston Gray watermelon with the yield of 50 tons/ha and Honey Drop melon with 20 ton/ha, using drip irrigation system. Sprinkler system was not suitable due to high evaporation rate of water in this region. Furthermore sand particles ejecting from soil surface during sprinkling-drop impact damaged crop leaves and consequently decreased yield. Since infiltration rate in sand dunes is very rapid, conventional irrigation methods such as flood or furrow irrigation are highly inefficient. Thus implementation of the results of this research by farmers can play an important role in increasing water use efficiency as well as their livelihood.

[1] Asphalt Moisture Barrier

Keywords: AMB layer, Stabilized sand dune, Drip irrigation, Sprinkler irrigation, Cash crops. Summer crops

INTRODUCTION

The dune systems of most arid zones are very rich in plant species in contrast with heavy texture soil under the same ecological conditions (Ranwell, 1972). Indeed in comparison with heavy clay soils, small amount of water in sand texture can have a considerable effect on plant growth and its establishment due to low suction force for available water in sand materials. In arid zone where evaporation considerably exceeds the amount of rainfall, detailed study of water availability, type of irrigation for crop production in sandy plains and dune can be very important (Kulic, 1979). Large portion of the study area (Lower Karkheh River Basin or LKRB) are covered by blown sand with the thickness of 1 to 40 meters. The total area of dune covered lands of LKRB has been estimated about 120,000 hectares.

The region has a semiarid to arid climate with an average annual temperature of 25 C. The average annual precipitation is about 180 mm with a large interannual variability. The rain mostly falls in autumn and winter seasons.

Sand dune stabilization in the region has been obtained by the following different but complementary methods:

1. bituminous mulching)on very active sand dune)
2. palisading (stem of phragmites, mostly)
3. biological stabilization by providing plant cover (on less active dunes)

A considerable portion of these dunes in the project area has already been stabilized ,and good covers of annual and perennial species have been established. Here again this very successful program of sand dune fixation has raised another problem, once the protection is ensured, how to economically use this land.

Three main possibilities may be considered:

- production of firewood
- production of pasture and animal products
- production of agricultural crops, where water for supplementary irrigation is available

Production of firewood does not appear to be an economically viable option (Le Houerou,. 1875). Production of pasture such as Panicum and agricultural crops on the other hand is quite possible. Dunes are equally suitable for growing cash crops but their fertility appears to be a limiting factor. Growing pastures plants and grazing it lightly has been proposed as a way of utilizing the stabilized areas of the dunes for food production. However, the delicate balance, which now exists in the stabilized dunes, could be disrupted very easily when grazing is not practiced under strict regulations. Thus in order to utilize the stabilized sand dune systems more efficiently, some high value crop or cash crops production is another alternative, where irrigation water is available. Since infiltration rate in sand dunes is very rapid, conventional irrigation methods such as flood or furrow irrigation are highly inefficient. To overcome water efficiency problem, slow application of water through drip or trickle irrigation with the irrigation pipes placed on the soil surface or used as subsurface irrigation can be practiced. Currently several community groups are using dunes for watermelon production but they use the highly inefficient method of furrow irrigation (lined by plastic sheet).

Site description

The Study area is located in the Khuzestan province, 25 km north of Ahwaz city and west of the Ahwaz-Andimeshk highway. The geographical position of the area is located along 31º, 20´ of the northern latitude and 48º, 40´ of the eastern longitude. The Altitude of the experiment site is 20 meters from sea level. Average annual precipitation, is about 150 to 200 and annual pan evaporation is also more than 2500 mm for a 30 years recorded data. Relative humidity varies between 60 to 70%, and the maximum absolute temperature of the region has been reported at 50 Celsius C. The dry seasons normally starts from May and extends till end of November. The original soil in the region is an alluvial soil with heavy clay texture that has been developed from Karkheh and Karoon river sediments. In the study area this alluvial soil is covered by dune systems due to action of wind erosion processes. The level of calcium carbonate in sand dune is varied between 20-40%. It was found that most sand dune systems in the study area are composed of 95 percent of fine-sand particles and clay/silt fraction contributed only about 5 percent to the total texture. Water holding capacity was about 5-6 percent by weight and wilting point was around 0.75-1.5 percent for some native shrubs investigated (Rouhipour, 1994a). The average depth of water table in the area is about 3-4 meter with high salinity around 14 dS/m of electrical conductivity. Some Physio-Chemical analysis of sand samples is indicated in table 1.

Table 1.Some physio-chemical characteristics of the soil samples taken in the study area

Sample No	Depth (Cm)	Sp (%)	K (ppm)	P (ppm)	N (%)	Gypsum (Me/100)	TNV (%)	pH	EC (dS/m)	Clay (%)	Silt (%)	Sand (%)
1	0-20	25	54	1.9	-	2.2	26.4	8.2	0.28	5.0	1.2	93.8
2	20-40	24	54	2.2	-	2.0	21.8	8.1	0.27	3.0	1.2	95.8
3	40-60	24	60	2.0	-	2.0	19.2	8.0	0.28	3.0	1.2	95.8

METHODS AND MATERIALS

Water Balance Equation

The fate of water in the ecosystems can be described with a mass balance equation that accounts for the major inputs and outputs within the limits that can be adjusted to the scale of interest.

For a given period of time and given area water balance can be stated as follows:

$P = E + T + D + R + \Delta w$

Where:

P is precipitation

E is evaporation (direct from the soil)

T is transpiration (direct from the plant)

D is deep drainage

R is surface runoff

Δ w is the change in soil water volumetric content

Usually these terms are calculated using units like millimeters. Changes in soil water content follow:

$\Delta w = P – E – T – D – R$ (1)

Despite the low evaporation in sand dune systems, (E in eqn. 1), the permeability of water into sand profile is too high compared with clay or loamy soils due to the presence of large pores between sand particles. Thus, in this kind of soil, plant roots can not access enough water, in particular for annuals plant such as crops used in this experiment with short rooting system. Surface runoff, R in Eqn. 1 in bare sand dune is also negligible due to very high infiltrability of water(Rouhipour, 1994b). Thus it seems the most of precipitation and irrigation water is lost through rapid percolation of water deep inside dune system.

In dry countries such as Iran, effective use of irrigation water obtained from restricted resources is very important. Thus in order to prevent water loss due to rapid infiltration in sand dune, some reliable techniques must be adopted to overcome this problem. Drip irrigation is an alternative technique currently being used in many countries. Other technique such as lining irrigation canals with plastic sheet or appropriate materials and sealing the bottom of reservoir are also in progress.

AMB layer

In this experiment, to prevent water percolation, a layer of asphalt was applied as a barrier at appropriate depth below the root zone. This layer is called Asphalt Moisture Barrier (AMB). The AMB is made of asphalt materials of type 60-70 that lay under the ground surface to prevent water from passing through the barrier. The ratio of sand particles and asphalt is normally depends on the type of sand. Asphalt with 170°C when laid in dry sand will makes a mixed- layer sand equal to 170% of the asphalt weight. On the other hand, asphalt has an elongation percentage of 1200 for pure asphalt and 250 to 300 for asphalt containing sand equal to 170% of asphalt weight mentioned before. This means that an AMB of 3mm thick forms a barrier tight enough to prevent water from passing through it.

To construct AMB layer in dune sand, a special tractor was used (D150-1). This machine is equipped with an asphalt tank, asphalt melting device, asphalt suction pump, housing system to convey melting asphalt, a special ripper, and asphalt sprayers consist of a series of nozzles(Photo 1. from Kumatsu Ltd 1975).

The melted asphalt was sprayed at a pressure of 4 kg/cm^2, at two different depths of 45, and 60 cm under the sand surface. The insertion of melted asphalt was carried out as 2 m strips under the sand surface. To make sure that the coverage of the layer under the sand is complete, 10% overlap was created between two adjacent stripes, while machine was operating back and forth in each round. The insertion of this layer, allows rainfall and irrigation water to be conserved and remain easily accessible to plants.

Vertical Barrier and Drainage

In some experimental plots, rainfall or irrigation water that retained above the barrier could escape out of plot from the natural horizontal drainage system at the exit end of plots along the ground inclination. Thus to prevent the saved water, it is necessary to provide a vertical barrier intersecting the horizontal barrier (called the vertical AMB) at the edge AMB field. Fig.1 shows the AMB layout including plots with and without vertical barrier. Each strip of

AMB layer consists of a 3m width and 340m length that can be formed with each pass of the AMB Machine. It is possible to cover a wide range of area by putting a number of strips of AMB side by side.

Experimental Design

Twelve test plots of approximately o 2 hectares were constructed in the study area after levelling dune sands. The whole plots were then divided into two groups, 6 plots with inclination of 1/200 and the other 6 plots without inclination. The first 6 plots with 1/200 inclination again divided into another two groups, namely irrigated and none irrigated. In both groups 4 plots were allocated for AMB layer either at a depth of 45 or 60 cm respectively together with the vertical barrier and the other two plots left for non AMB layer as check plots. The same procedure was applied for the second groups of 6 plots but no inclination was designed (see AMB layout in Fig.1). Drip irrigation system was applied for all those plots allocated for irrigation treatments. Before carrying out the maim experiment, a preliminary investigation was conducted between the two methods of irrigation (sprinkler versus drip irrigation). This experiment indicated that sprinkler-irrigation was not suitable for such conditions in the region described earlier.

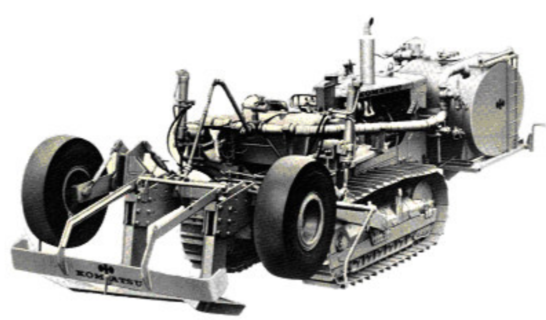
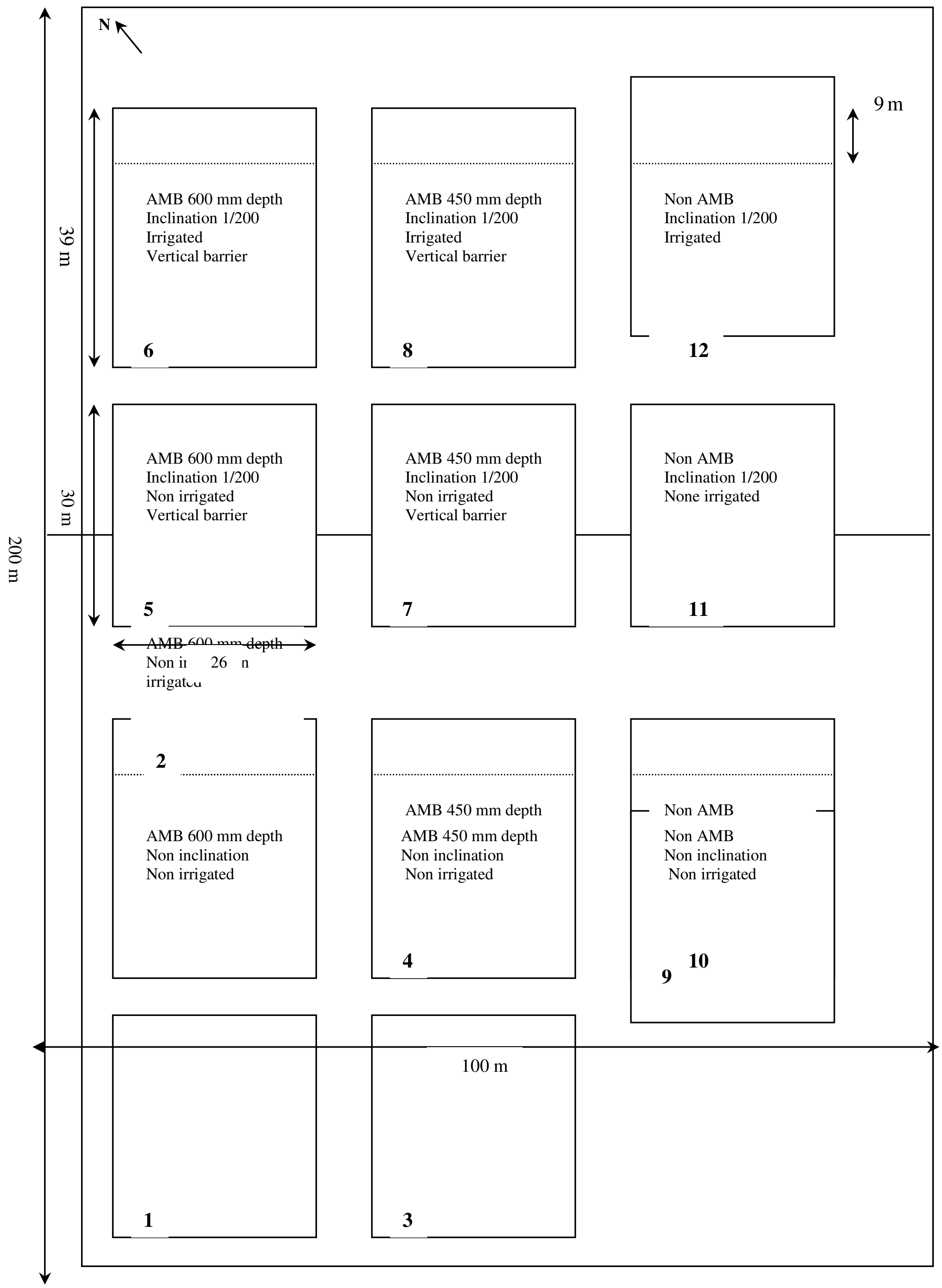


Photo.1 Tractor D150-1 designed for injecting AMB layer in sand dune


N
9 m
39 m
30 m
200 m
AMB 600 mm depth
Inclination 1/200
Irrigated
Vertical barrier
6
AMB 450 mm depth
Inclination 1/200
Irrigated
Vertical barrier
8
Non AMB
Inclination 1/200
Irrigated
12
AMB 600 mm depth
Inclination 1/200
Non irrigated
Vertical barrier
5
AMB 450 mm depth
Inclination 1/200
Non irrigated
Vertical barrier
7
Non AMB
Inclination 1/200
None irrigated
11
26 m
AMB 600 mm depth
Non inclination
Non irrigated
2
AMB 450 mm depth
AMB 450 mm depth
Non inclination
Non irrigated
4
Non AMB
Non AMB
Non inclination
Non irrigated
10
9
100 m
1
3

Plantation of cash crops

After initial irrigation 5 different cash crops such as watermelon, rock melon, cucumber and tomato were chosen and planted in all plots under investigation. The whole area under study was 2 hectares, partly with AMB layer at two different depths and plots without AMB as mentioned before.

For each experimental plot, commercitial elite seeds from 5 kinds of cash crops were selected, and planted in several rows as follows:

1. Tomatoes seedling (Red cloud variety) was planted in 3 rows (the distance between the rows was 1m, and 0.5 m between the seedlings). Each row contained 50 watermelon seedlings.
2. Watermelons (Charleston grey) were planted in 6 rows (the distance between the rows was 2m, and 0.5m between the seedlings). Each row contained 50 watermelon seedlings.
3. Watermelon (Ibuki, Japanese hybrid) watermelon was planted in 4 rows. The distance between the rows was 2m, and 0.5m between the seedlings). Each row contained 59 watermelon seedlings.
4. Rock melons (Honey drop, Japanese hybrid) were planted in 4 rows. The distance between the rows was 2m, and 0.5m between the seedlings). Each row contained 59 watermelon seedlings.
5. Cucumbers (Tokyo slicer, Japanese hybrid) were planted in 4 rows. The distance between the rows was 2m, and 0.5m between the seedlings). Each row contained 59 watermelon seedlings.

Direct seeding in plots was used for all crops except for tomatoes in which seeds were first sown in the nursery and then transplanted in the experimental plots as seedlings.

For irrigation of watermelon, rock melon, and cucumber, a 2L/h-type dripper was used for each crop seedling and 4L/h for each tomato seedling. (Photo 2).

To insure that sufficient amount of water was supplied for all crops, daily irrigation water was calculated based on daily measurement of class A- pan evaporation. Irrigation was carried out over the period of 4^{th} Mach-16^{th} June. During the growth periods, till harvesting time for all crops, 3438 m^3 of water was used at rate of approx. 30 m^3 per day.


Photo 2. First stages of crop establishment in AMB plot with drip irrigation lines

Chemical fertilizers used

Since nitrogen is one of the basic plant nutrients, in this experiment based on soil analysis, the urea fertilizer was applied in the form of solution at the rate of 300kg/hectare, through the fertilizer tank of drip-irrigation system. Thus for daily irrigation 3 kg of urea solution was applied to crops by irrigation pipe and drippers. Ammonium phosphate which is not soluble in irrigation water was added directly to soil as strip application in close contact with crop stands at the rate of 100kg/hectare.

Other tonic nutritional fertilizer such as phosphorus, potassium, nitrogen and micro nutrients in the form of solution were also applied to crops through the fertilizer tank and irrigation pipes at rate of 10L/hectare.

Pest and disease control

In order to protect all crops from plant diseases and pests, all seedlings of watermelons, rock melons, cucumbers, and tomatoes were sprayed with appropriate insecticide and, fungicide during the all stages of plant growth. The most important pest that appeared during the course of this experiment was watermelon pest, which could potentially damage the watermelons. This pest, which was seen in this area for the first time, was identified by the Khuzestan's Research Institute of pests and diseases.

Method of Statistic analyses

Data on different stages of crops growth, such as, date of blossoming, fruit appearance, as well as harvest date were collected (photo 3, table 2). Due to the fact that designing the replicated plots for each treatment in a large experimental area (2 hectares) was not possible particularly with AMB treatments which needed tremendous earth works, statistical analysis was changed in such a way to solve this problem. Thus to be able to compare the results of harvested yield for each experimental plots (presence or absence of AMB layer and irrigated and non irrigated plots), every row of plantation for each crop was divided into five equal segments as experimental replication. The yield of each segment for each crop was then measured and considered as a replication for the same crop and analysed. In other words, for each treatment we had five replications. Thus any possible errors in the results of this study could be due to the inevitable method used for this kind of analysis. Even though the simple analysis of the comparison between means could have resulted in an approximate conclusion in determining the better treatments (for the most crops the difference in harvested yield was too big). Therefore as stated above, the F test and variance analysis was carried out here to show the results.

Table 2. Date of sowing, planting seedling, flowering and harvesting yield of crops under investigation

Crops	Final harvest	First harvest	Blooming	Planting
Cucumbers	8 June	3 May	17 April	26 Feb-1March
Rock melons	21 June	24 May	4 April	26 Feb-1March
Watermelons	21 June	24 May	17 April	26 Feb-1March
Watermelon (Japanese)	21 June	23 May	17 April	26 Feb-1March
Tomatoes	26 June	6 May	30 March	5 March (seedling)

Photos.3 Water melon harvesting time in AMB plot using drip irrigation

RESULTS:

Table 4 shows the mean harvest of the 5 crops in the irrigated timars. The harvest from the timars without irrigation was insignificant. Therefore the conclusions were drawn only for the irrigated treatments to show the effect of AMB and vertical barrier on crops yield as follows:

Watermelon (Charleston grey)

1. The presence of the AMB layer for the both depths (60 and 45 cm) showed a significant difference in harvested yield compared to plots without AMB layer. High yield for plots having AMB layer beneath the sand surface.

2. There was no significant difference in the level of yield for plots with AMB layer at a depth of 45 and 60 cm.
3. There was no significant difference for plots with or without a vertical barrier for both depth of AMB.

Watermelon (Japanese variety Ibuki)

1. The presence of the AMB layer at both depths gave rise to a higher level of yield compared to non AMB and the difference was significant.
2. There was no significant difference between AMB plots at a depth of 45 and 60 cm in terms of harvested yield.
3. There was a significant difference between AMB plots at a depth of 45 and 60 cm having a vertical barrier. Plots at a depth of 45 cm AMB gave a higher yield.

Cucumbers (Tokyo slicer)

1. Same as other crops investigated, the effect of AMB layer on cucumbers yield was significant when compared to a non AMB plots with lower yield.
2. AMB plots at a depth of 45 cm gave more yield than 60 cm AMB plots.
3. AMB plots at a depth of 45 cm with the vertical barrier were much superior to the same plots without a vertical barrier.

Rock melon (honey drop)

1. There is a significant difference for yields harvested of plots with AMB layer and non AMB. AMB plots gave higher yield than plots without AMB.
2. AMB layer at 45 cm depth was much better than 60 cm AMB.
3. The effect of vertical barrier was not significant for plots having AMB at a depth of 45 cm but significant for 60 cm AMB.

Tomatoes (Red cloud)

1. Although tomatoes gave no considerable yield in this experiment compared to other crops but plots with AMB layer was much better than non AMB.
2. The vertical barrier for both depths (45 and 60 cm) was better plots without vertical barrier.
3. There was no significant difference between plots at a depth of 60 cm AMB and 45 cm AMB.

Table 3. Average yield (Ton/ha) of crops in stabilized sand dune using AMB together with drip irrigation system

Plot No	Cucumbers (Tokyo slicer)	Rock melons (Honey drop)	Watermelon (Ibuki)	Watermelon (Charleston gray)	Tomatoes (Red cloud)
2	2/50	13/90	32/50	49/60	2/70
4	9/00	26/84	34/90	55/90	7/10
6	6/50	24/90	25/56	51/80	18/20
8	11/50	25/16	31/80	50/20	15/80
10	0/60	4/53	13/00	5/90	0/12
12	0/95	2/76	7/30	13/90	1/00

CONCLUSION

This experiment was initiated to show the role of moisture barrier and some irrigation techniques for conserving water in sand dune system and also to demonstrate the potential of sand materials for growing cash crops. Overall, it was concluded that:

1. Dry farming of cash crops in this region on sand dune with and without AMB was not successful.
2. Application of AMB in dunes sand using drip irrigation was highly efficient for all crops investigated
3. AMB layer at a depth of 45 cm was much better than 60 cm AMB for most of crops investigated. This is possibly due to ability of crop- root system to be extended in the soil profile.
4. Vertical barrier was effective in increasing yield for most of crops particularly when used with 45 cm depth of AMB

This experiment indicated spectacular results in the production of watermelon (Charleston gray), with the yield of 50 tons/ha and rock melon (Honey drop) with 20 ton/ha, using drip irrigation system (Table3). Sprinkler system was not suitable due to high evaporation rate of water in this region. Furthermore sand particles ejecting from soil surface during sprinkling-drop impact damaged crop leaves and consequently decreased yield. Since infiltration rate in sand dunes is very rapid, conventional irrigation methods such as flood or furrow irrigation are highly inefficient. Thus implementation of the results of this research by farmers can play an important role in increasing water use efficiency as well as their livelihood.

REFERENCES

Komatsu Ltd. 1975. Application of Asphalt Moisture Barrier Layer to Desert Development Project, (Interim Report). Japan, 41 p.

Kulic, N. F. 1979. Water budget and moisture balance of various landscape types of sands in arid zone. International research courses on fixation of shifting sands. Moscow. Ashgabat

Le Houerou, H.N. 1875. Report on a consultation mission to the Range Organization of Iran. Food and Agriculture Organization of the United Nations, Rome, 12p.

Ranwell, D.S. 1975. Ecology of salt Marches and sand dune. Chapman and Hall.258p

Rouhipour. H. 1994a. Determination of critical height of Khuzestan sand dune system (1994). Publication No 112**,** (in Persian language). Research Institute of Forests and Rangelands. Tehran, Iran. 108p.

Rouhipour. H. 1994b. Water balance in dune systems of dry regions Publication No 94**,** (In Persian language). Research Institute of Forests and Rangelands. Tehran. Iran. 40p.

.