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# Rain Water Harvesting Systems is a Way for Water Conservation

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**Abstract:** Arid and semi-arid areas can be utilized by using rain water harvesting techniques to increase animal and agriculture production in such areas. To that end, the Agricultural Research (ARC) center in the Libya in Cooperation with the International Center for Agricultural Research of Dry Areas (ICARDA) have vitalized a project of rain water harvesting. The project aims at studying the old traditional methods used in W.H., evaluating them technically and economically as a first stage, then conducting researches and studies for optimum utilization of rain water harvesting techniques by developing those techniques and introduce new ones. In this frame work, as a first stage, the formed team for this purpose conducted field survey and comprehensive compilation of old and modern methods utilized in rain water harvesting existing in the western area of Libya and classifying them according to the size of catchement area and water storing method, whether being in soil, in ground reservoirs or behind dams. Following completion of this stage, members of the team carried out some field experiments, by applying W.H. techniques such as Nigarims and contour lines in developing natural pasture in semi arid region in westren Libya using Atriplx shurbs. Although tangible results were not achieved in the first year of the experiments carried out in 98/99 season due to scanty rain, as quantity and density, but by the end of 99/2000 season a good growth of the shurbs used in the experiment have been noticed comapred with the ones planted outside the techniques.

**Key words:** Arid • Harvesting • Water • Libya

## INTRODUCTION

Libya is considered as one of the arid and semiarid countries that face very severe water scarcity. Because of that, water resources are considered the most important natural resources that should be subjected to good management and scientific evaluation to get the most benefit of them. The conventional water esources in Libya are groundwater and surface water. The groundwater represents the main source and constitute around 97% [1] of consumptive water in different fields, whereas surface water contributes with 2.5%. The main source of surface water is the rainfall which ranges in average from around 400 mm/year in the north to less than 10 mm/year in the Sahara desert in the south. Different rainwater harvesting techniques have been used to get the most benefit of rainfall water specially in foothills and mountains areas. Storage and prevention dams, cisterns, contour lines and lunar basins have been used for gathering rainfall water during rainy season that flows through the existing Wadis which is extending between the mountains area in south and Mediterranean Sea in north. These rainwater harvesting infrastructure have deteriorated due to lack of maintenance and being at low-priority and it continued to be abandoned. To revive these techniques, especially when available water resources became either reduced in quantity or/and quality under the pressure of population growth and economic expansion, the Agricultural Research Center (ARC) in Libya in cooperation with the International Center for Agricultural Research of Dry Areas (ICARDA) had lunched a program to demonstrate the usefulness of rainwater harvesting techniques in rainfed farming and animal production. The purposes of the program were to evaluate the existing rainwater harvesting techniques as a first stage, then conducting field experiment to evaluate rainwater harvesting techniques for effective soil-moister storage and improved biomass production. The formed team for this purpose conducted field survey and comprehensive compilation of old and modern W.H. techniques existing in the western area of Libya. Following the completion of this stage, members of the team carried out the field experiment. Two rainwater harvesting techniques, Nigarims and Contour ridges, for developing natural pasture in semi arid region in westren Libya using Atriplx shurbs were used.

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Fig. 1: Storage / Recharge Reservoir

Fig. 2: Wadi Flow Diversion Structure

Fig. 3: Lunar basins used to grow Fug trees Flow

Fig. 4: Bridges and Banks constructed in the wadies floor

The experiment was carried out in 98/99 season and continoued until 99/2000 season. In spite of the fact that tangible results were not achieved in the first year of the experiments due to scanty rain, as quantity and density, but by the end of 99/2000 season a good growth of the shurbs used in the experiment have been noticed comapred with the ones planted outside the techniques as a control ones.

**Stage 1:** A survey was conducted on exiting water harvesting techniques that are located in the Al-Gharbi Mountain south west of Tripoli, Libya. They were classified according to the size of the catchment area as follows:

**Macro-catchment Water Harvesting:** Storage, recharge or check dams are used to conserve the soils and water through minimizing energy level due to flood wave routing in reservoir and storing the water in surface or sub-surface reservoirs through replenishing the under the ground waters. The stored water is latterly used for biomass production. Figure 1 shows a view of storage/recharge reservoir. Government constructed a number of such dams. Zarat and wadi Ghan dams are a few examples. Diversion and re-distribution of floodwater is done in order to minimize the erosive action of flowing water and also to delay flow time and encouraging soil-moisture storage as well as recharging the groundwater aquifer wherever possible. Figure 2 shows a wadi flow diversion structure. The inhabitants constructed most of these structures, either on individual or community level.

**Micro-Catchment Water Harvesting:** Lunar basins were constructed on deep soils in order to meet the crop-water requirements of growing trees. This technique was mainly applied in urban areas. Figure 3 shows a view of trees grown with the help of this technique. The farmers also used this technique in Gharian city to grow olive, fug and almond trees, where deep soils and high average rainfall occurs. The term bridging and banks is used to construct earthen dikes on the wadies floor in order to allow runoff from side slopes of the wadi to accumulate in front of these dikes. The water is stored as soil moisture and is used to grow trees. Figure 4 shows this system.

**Main Constraints and Improvement Potential:** Existing water-harvesting systems were generally based on the local experience without adequate investigations of rainfall, its transformation into runoff and transmission of runoff at downstream as overland and stream flows. The systems had badly been suffering due to floods and drought. Moreover, lacking in management capacity and proper maintenance, the existing systems could have following consequences:

- Soil loss from the watersheds are continuously depositing in the existing reservoirs. This is resulting in reduced water storage capacity and lowered infiltration/ groundwater recharge from the reservoirs. This phenomenon is time dependent, therefore, deteriorating conditions are likely to aggravate in future. Rapid reservoir sedimentation could occur in the watersheds with high sediment delivery ratio.
- Breaching of existing dams either due to overtopping in the result of intensive rainstorm or because of hydraulic phenomena such as seepage, piping, undermining etc., could lead to disastrous failure and might result in excessive erosion and lives losses on site and at the downstream.
- Sever consecutive drought has badly affected the agriculture in the project area. If drought persists, the existing orchards are not likely to be survived and a great loss of biodiversity is almost certain.

**Stage 2**

**Evaluation of Rainwater Harvesting Techniques Experiment:** The experiment aimed at evaluation of water harvesting techniques. It is directly related to assess the water resource and its capturing potential and options for water utilization.

**Objectives:**

- Tested and verified, water harvesting and efficient runoff utilization techniques for effective soil-moisture storage, improved biomass production and reduced soil losses.
- Ecology-based knowledge of runoff potential per unit catchment area, under prevailing geo-physical and agro-climatic conditions and also with potential improvements.

## MATERIAL AND METHODS

The experiment aimd at real-time testing and evaluating two potential micro-catchment rainwater harvesting techniques in order to improve bio-mass production in a certain agro-climatic and geo-physical environment, which largely prevails in the northern areas of Libya [2].

**Experiment Site:** The experiment site is located at Gharian Pasture Project, Gadama, at about 40 km south of Gharian city (13° 6' longitude and 31° 55' latitude). Figure 5 shows the project location and Isohyetal map. The site represents a large area with similar characteristics and it is in easy approach to manage. Moreover, it is located in a region designated as grazing area, which is in match with the project objectives. Australian Atriplex was tested for its succession by using contour lines and Negarim basin rainwater harvesting techniques. The main characteristics of the area around and the experiment site are as follows:

**Climate:** Climate plays an important role in biomass production. Extreme climatic conditions and high inter-annual/ seasonal variability of climatic parameters could adversely affect the productivity.

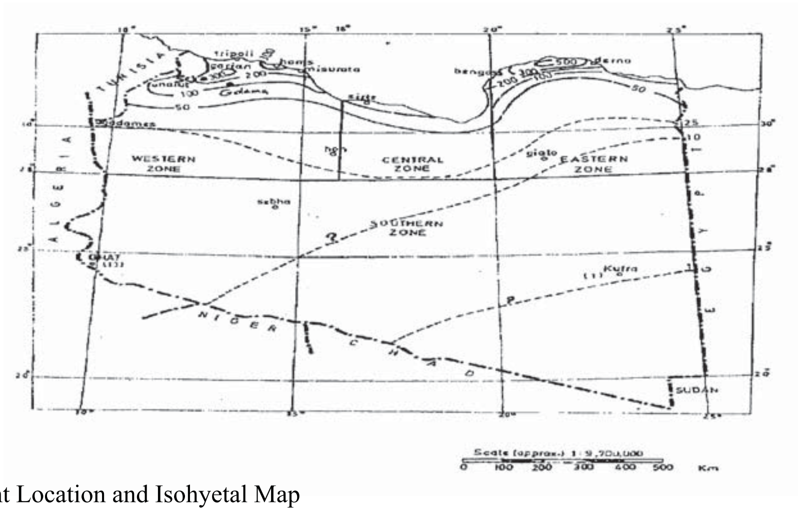


Fig. 5: Experiment Location and Isohyetal Map

Table 1: Long-time average of rainfall at Gadama station for 25 years (78/79 to 02/03)

| Month | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Main Rainfall(mm) | 24 | 22 | 21 | 4.5 | 2.4 | 0.8 | 0.4 | 3 | 9 | 19 | 20 | 18 | 144.1 |

Table 2: The water requirement for Atriplex in the experiment location

| Month | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $ET^0$ | 2.7 | 4.0 | 5.0 | 6.9 | 8.5 | 9.4 | 9.2 | 8.36 | 6.01 | 5.4 | 3.73 | 3 | 2197 |
| Kc | 0.4 | 0.4 | 0.5 | 0.6 | 0.6 | 0.7 | 0.7 | 0.6 | 0.5 | 0.5 | 0.4 | 0.4 | |
| ETc | 1.1 | 1.7 | 2.3 | 3.8 | 5.3 | 6.6 | 6.0 | 5.0 | 3.1 | 2.4 | 1.6 | 1.1 | |
| ETc(mm) | 36 | 47 | 70 | 114 | 164 | 198 | 186 | 156 | 92 | 75 | 48 | 35 | 1221 |

$ET^0$: Max Evaporation (mm/day)

$ET = Kc \times ET^0$

Etc: water requirement for the Atriplex ( mm)/yr

Table 3: Design parameters of contour ridges and Negarim micro-catchment water harvesting basins

| | Contour ridges | | | Negarim basin | | |
|---|---|---|---|---|---|---|
| C/CA | Mark | Total area (m$^2$) | Distance between ridges (m) | Mark | Basin total area (m$^2$) | Basin dimensions (m*m) |
| 12:1 | C1 | 10.2 | 6.8 | N1 | 10.2 | 3.2*3.2 |
| 15:1 | C2 | 12.5 | 8.4 | N2 | 12.5 | 3.6*3.6 |
| 18.75:1 | C3 | 15.5 | 10.4 | N3 | 15.5 | 3.95*3.95 |

Therefore, it is worth to examine the temporal variation of climate at the study site before launching an experiment. The study area is characterized by its semi-desert climate. Long-time data of nearby stations (Gadama Station) shows an average annual rainfall of 144 mm and average annual of maximum and minimum temperatures being 23.3°C and 13.3°C respectively. Temperature may go above 40°C in summer and drop below zero in winter. Table 1 shows the month-wide main rainfall.

**Topography, Soil and Land Cover:** The topography is rolling and undulating with slope variation between 2 and 20%. Dominant ground slope at experiment site is about 5%. A soil profile at the site indicates that the soil consists of 30 cm thick silt over a deep fragile layer limestone. It was noticed that plant roots have penetrated deeply into this layer. The soil can be classified as Calcic Xerofluvents.

**Experimental Design:** The experiment aimed at verifying the difference of biomass production with and without using water-harvesting techniques [3] and to quantifying this difference among control and two treatment cases.

A recording rain gage was available near the experiment site and is the main source of site-specific rainfall data. The gage is a part of weather station that had been established during 1978. Despite of the fact that the most important equipments are available, only the rainfall quantities are regularly recorded.

Two potential rainwater-harvesting techniques i.e. Contour ridges and Nigarim basin were evaluated [4]. The ratio of catchment to cultivated area (C/CA) was calculated on the basis of rainfall, effective root zone, crop-water requirement and runoff coefficient [5]. The procedure of calculating C/CA ratio was as following:

From Table 2 the crop-water requirement is 1.221 m/year. The average annual rainfall in the region is 144 mm. By assuming that the average diameter of the effective root zone for the Atriplex is 1 m, so the area of the effective root zone is 0.785 m$^2$.

The water requirement for each shrub=0.785x1.221=0.958 m$^3$ / yr

The quantity of water that can be collected by the root zone is:

$$0.785 \times 1.44 = 0.113 \text{ m}^3/\text{yr}$$

Therefore, the quantity of water that should be collected through W.H. technique is: 0.958 -. 113 = 0.845 m$^3$ / yr.

Since there was no an experimental estimation of the runoff coefficient in the region of the experiment, it was taken 50% based on the Rational Method and Cook methods [6], which take in consideration the slope, soil type and plant cover. So, the amount of rain that gives runoff 0.845 m$^3$/yr is:

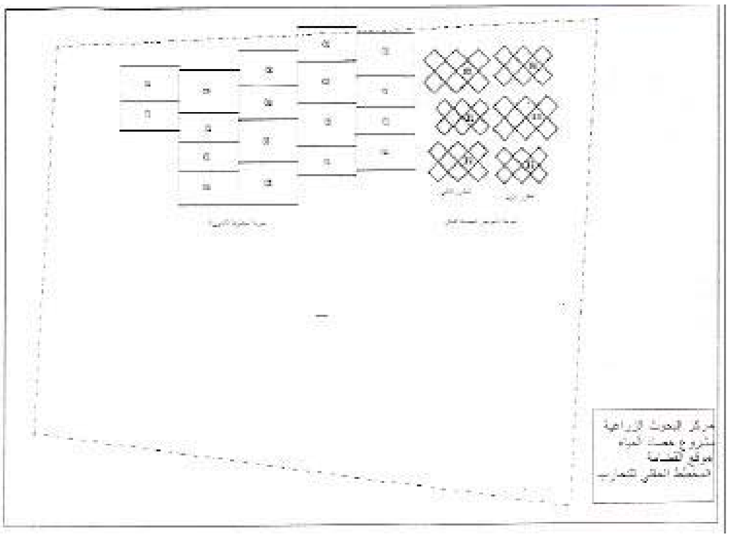

Fig. 6: Layout of Atriplex experiment plots

Table 4: Monthly and mean-monthly rainfall in mm at Qdama for period 1997-2001

| Year | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | June | July | Aug | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1997-98 | 74.5 | 38.0 | 0.0 | 26.5 | 49.0 | 13.0 | 54.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 255.2 |
| 1998-99 | 0.0 | 0.0 | 17.5 | 17.0 | 26.0 | 61.1 | 24.1 | 0.0 | 0.0 | 0.0 | 0.0 | 13.5 | 159.2 |
| 1999-2000 | 8.7 | 0.0 | 19.8 | 54.0 | 16.2 | 75.9 | 0.0 | 0.0 | 6.2 | 0.0 | 0.0 | 0.0 | 180.8 |
| 2000-01 | 0.0 | 94.0 | 0.0 | 0.0 | 16.3 | 80.8 | 0.0 | 6.2 | 0.0 | 0.0 | 0.0 | 0.0 | 197.3 |
| Mean-monthly rain | 20.8 | 33.0 | 9.3 | 24.4 | 26.9 | 57.7 | 19.6 | 1.6 | 1.6 | 0.0 | 0.0 | 3.4 | |

$0.845/0.5 = 1.69\ m^3/yr.$

**The Area Required for Collecting this Amount:** $1.69/0.144 = 11.736\ m^2$.

Catchment area + cultivated area = $11.736 + 0.785 = 12.521\ m^2$.

Catchment to cultivated area (C/CA) 11.736: 0.785 = 15: 1

Three replicas of each technique were tested in order to minimize the experimental error. The three sets with C/CA of 15:1, 12:1 and 18.75:1 were developed. The design parameters for contour ridges and Negarim basin are give in Table 3.

Field layout of experiment is shown in Figure 6. Atriplex was cultivated in each micro-catchment

**Data Collection and Analysis:** The rainfall events for a period from 1998 – 2001 were recorded at rain gauge. Rainfall data of these events was collected from the rain gauge record.

Atriplex growth was recorded at each micro-catchment, by the end of year 2000/2001, which includes plant height, crown diameter and plant maturity. A summary of collected data is given in Table 4 below.

## RESULTS AND DISCUSSION

Rainfall data at Qdama from years 1997-2001 is presented in Figure 7(a), which shows an average annual rainfall of 199 mm. A comparison between long-time average (144 mm) and the average during study period reveals that as a whole the study period yielded high average and can be regarded as relatively wet period. Examining the data infers that 2–3 events of rainfall equal to or greater than 30 mm occur in every season. This means that a significant chunk of the annual rain falls in these 2–3 events and is thus available for shorter duration if not properly stored. However, it needs confirmation based on long time rainfall events record.

Knowledge of month-wide distribution of rainfall is important to know the amount of water available for the biomass in rain-fed areas. Figure 7(b) shows mean-monthly and monthly rainfall at Qdama for the study period. Monthly rainfall also shows a high variability. Based on four-year data, it shows zero rainfall in one of the four years (December is rainless for 25% of time), two out of four years (September, October, November and March are rainless for 50% of time), three of the four (April and May are rainless for 80% of time). January and February receives rainfall for 100% of time.

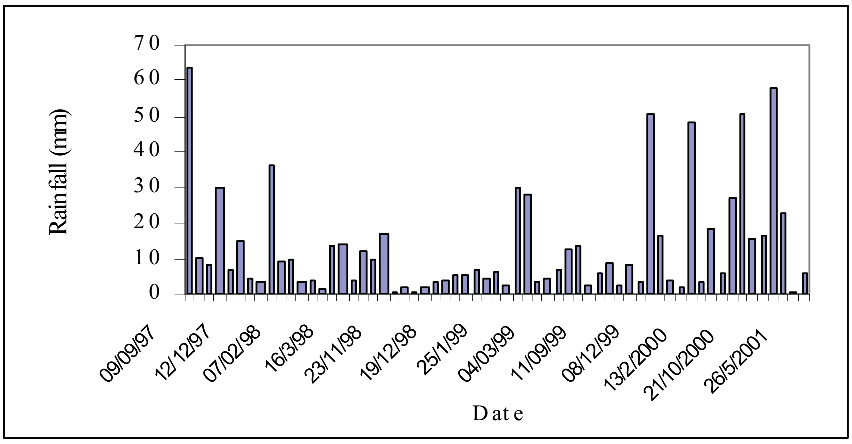


Fig. 7(a): Event rainfall at Qdama, from 1997-2001

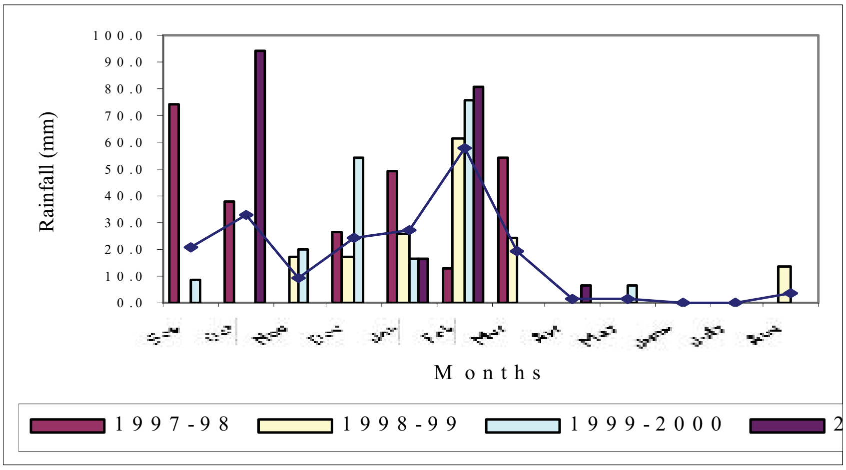


Fig. 7 (b): Monthly and mean-monthly rainfall at Qdama during (97-2001)

Table 5: Summary of collected data on plant succession

| Treatment | Cultivated area $m^2$ | Catchment area $m^2$ | Total area $m^2$ | Avg plant height cm | Avg crown length cm | Avg diameter cm | Biomass $cm^3$ | Maturity% |
|---|---|---|---|---|---|---|---|---|
| Control | | | | 53.0 | 26.0 | 49.0 | 49004 | 16 |
| C1 | 0.785 | 9.4 | 10.19 | 59.0 | 57.0 | 90.0 | 362435 | 66 |
| C2 | 0.785 | 11.7 | 12.49 | 53.0 | 53.0 | 71.0 | 209731 | 51 |
| C3 | 0.785 | 14.7 | 15.49 | 62.0 | 28.0 | 110.0 | 550913 | 79 |
| N1 | 0.785 | 9.4 | 10.19 | 56.0 | 25.5 | 75.0 | 112598 | 44 |
| N2 | 0.785 | 11.7 | 12.49 | 55.5 | 39.0 | 71.0 | 154330 | 50 |
| N3 | 0.785 | 14.7 | 15.49 | 58.0 | 42.0 | 83.0 | 2298875 | 62 |

The variability along mean is also high. It could negatively affect the biomass, if rainless conditions for the above-mentioned months continue for a couple of consecutive years.

For the Atriplex succession in relation to treatments, table 5 Shows the number of survived shrubs and the survival rate for both treatments. It also indicate that for plant succession, both treatments performed better than control case, when the performance of contour ridges with a catchment area of 14.7 $m^2$ was the best among all treatments.

Figure 8 (a) is based on summary results, which shows the variation in plant height, crown sizes and plant maturity in relation to control and three treatments of each contour ridges and Negarim basins. The results show a good survival for both the treatments and control case.

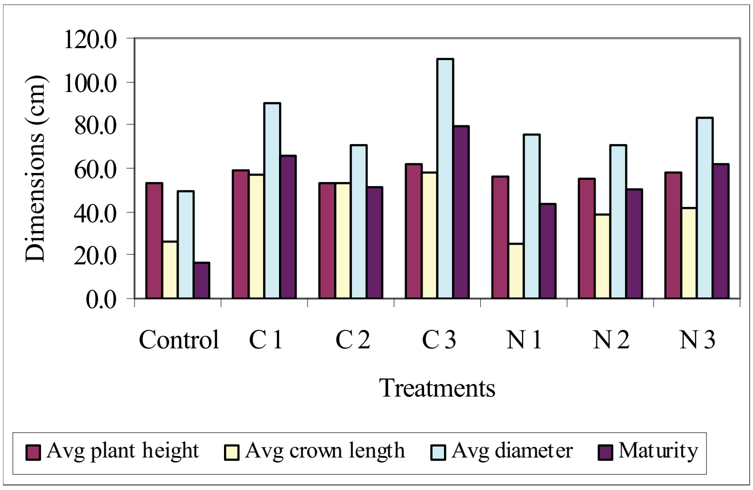


Fig. 8 (a): Plant height, crown sizes and maturity in relation to treatments

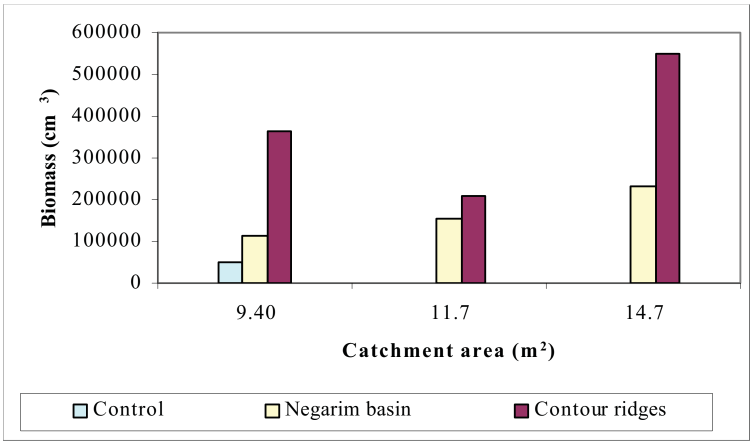


Fig. 8 (b): Biomass variation in relation to catchment area and treatments

Table 6: Survival rate of the Atriplex shrubs in the different treatment

| Year | Treatment | Total No. of shrubs | No. of survived shrubs | Survival Rate |
|---|---|---|---|---|
| 2000 | C1 | 60 | 60 | 100 % |
| - | C2 | 60 | 60 | 100 % |
| - | C3 | 60 | 60 | 100 % |
| - | N1 | 16 | 14 | 87.5 % |
| - | N2 | 16 | 14 | 87.5 % |
| - | N3 | 16 | 16 | 100 % |
| 2001 | C1 | 60 | 59 | 98.3 % |
| - | C2 | 60 | 59 | 98.3 % |
| - | C3 | 60 | 59 | 98.3 % |
| - | N1 | 16 | 11 | 68.75 % |
| - | N2 | 16 | 13 | 81.25 % |
| - | N3 | 16 | 13 | 81.25 % |

Figure 8 (b) shows the variation of biomass in relation to size of catchment area for Negarim basins and contour ridges. It indicates that biomass growth was higher in case of contour ridges as compared with Negarim basin for all three catchment sizes, however, the catchment area of 14.7 $m^2$ performed better than the catchment areas of 11.7 and 9.4 $m^2$ for both the treatments. The performance of contour ridges with the catchment area of 14.7 $m^2$ was best among all alternatives. The volume of biomass for treatments as compared with control case is higher by 2.3 to 11 times, which shows the usefulness of water harvesting techniques.

From Figure 8 the following conclusions can be drawn:

- The survival rate will decrease with time, but it will stop after certain time and this will happen only with good techniques.
- The survival rate for contour ridges is better than it for Nigarim technique, that is might has to do with the location and depth of soil where the Nigarim techniques were constructed.

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