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The results showed that the shoot length of *Acacia senegal* was more than *Acacia tortilis* subsp *raddiana* and *Zizphus spina christi.* The growth variables of the three tree species were significantly better ($P \leq 0.001$). The best height and number of leaves were recorded by *Acacia senegal.* The diameter of stem of seedlings of the three tree species showed variation in values. The growth variables of the three tree species planted in the pits were superior to those grown in the semi- circles.

I. Introduction

Water is essential to all forms of life human, animal and vegetation. It is therefore important that adequate supplies of water be available to sustain such life. Development of water supplies should, however be undertaken in such a way as to preserve the hydrological balance and the biological functions of all ecosystems, which is crucial for marginal lands. Water harvesting is the general name used for all the different techniques to collect runoff or flood water for storage in the soil profile or in tanks so that it can be used for the production of crops, trees or fodder. Water harvesting also can be the collection of runoff water for human or livestock consumption. The water harvesting methods strongly depend on local conditions and include such widely differing practices as ponding, pitting micro catchment water harvesting, flood water and ground water harvesting (Prinz, 1996; Critchley and Siegert, 1991). Water harvesting for dry-land agriculture is a traditional water management technology to ease future water scarcity in many arid and semi-arid regions of the world (Prinz and Singh, 2000). In Sudan, where the major part of it falls within the arid and semi-arid zones, different traditional water harvesting techniques and systems are being practiced since long and are still referred to in the literature by their traditional names, e. g. Haffir and Teru (Oweis *et al*., 1999). In Sudan, the climate ranges from arid in the north and northwest to wet-and-dry tropical weather in the southwest. In semi-arid zones of Sudan such as the west region, safe drinking water is rare. In particular, areas in North Darfur and South Kordofan states rely on groundwater supply (wells) or water storage methods called hafir or earth dams for their water supply. Rainfall collection is one of the water sources in Sudan and rainwater harvesting (RWH) methods implemented to improve the production of crops and livestock in the region. Several water harvesting techniques and agricultural practices were and still practiced by the local farmers, on sloping land and in areas with variable and unreliable rainfall, to reduce the risk of crop failure .Farmers adopted bench – terracing systems, for many thousands years ago, the signs of which are still found in hilly areas such as Jabel Marrah(HTS, 1958). In Kassala region, eastern Sudan, earth embankments (terus) are constructed to intercept sheet-wash runoff, from adjacent catchments, following heavy storms (Van Dijk and Ahmed, 1993), thus harvesting nutrients and controlling erosion (FAO, 1994).

Water is not only one of the world's most important resources, but also a scarce resource in many parts of the world. Water has always been a critical issue. It has been in short supply for many years, but the situation is alarming now. Water harvesting for aforestation is applied in arid and semi-arid regions where rainfall is not sufficient to sustain a good seedling / tree growth. Water harvesting can significantly increase the rate of tree establishment in drought prone areas by concentrating the rainfall/runoff.

Limited water availability is the primary factor controlling plant establishment and growth in the dry

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lands and deserts of the world. Water shortages are accentuated in disturbed areas where vegetation removal and alteration of the surface soil further limit surface water retention and infiltration into the soil. The construction of micro catchments, alterations in the topography of a site to direct precipitation runoff to plants, offers a low cost, passive means of increasing the amount of water available to plantings (Fidelibus and Bainbridge, 1995).

Rain water is good for plants because it is free of salts and other minerals that harm root growth. As rain water percolates into the soil, it forces salt down and away from root zone, allowing root to grow better and making plants more drought tolerant. For the maximization of the use of surface runoff rain water at Khartoum New International Air Port area in aforestration and tree cover some water harvesting techniques using *macro catchments were tried for different indigenes tree species*.

The objectives of this study were: (a) to investigate the influence of some water harvesting techniques on growth of three tree species namely; *Acaia tortilis sub sp raddiana, Acacia senegal, and Ziziphus spina Christi* (b) Determine the effect of the different water harvesting techniques on growth rate, shoot length, number of leaves, and stem diameter of the *Acaia tortilis sub sp raddiana, Acacia senegal, and Ziziphus spina Christi* seedlings. (c) Evaluation the effect of water harvesting techniques used in improving moisture conservation and increasing and stabilizing trees cover.

II. Material and Methods

The study was conducted around Khartoum New International Air Port (KNIA), to study the influence of three water harvesting techniques on trees growth rate and soil moisture content.

a) The study Area

i. *Location*

Khartoum New International Air Port (KNIA) is located in the south west of Omdurman, Khartoum State (Figure 1), at a distance of about 40 km south of Khartoum center and 25 km west of the White Nile River .It lies between latitude 15°13`N and longitude 32°19`E.

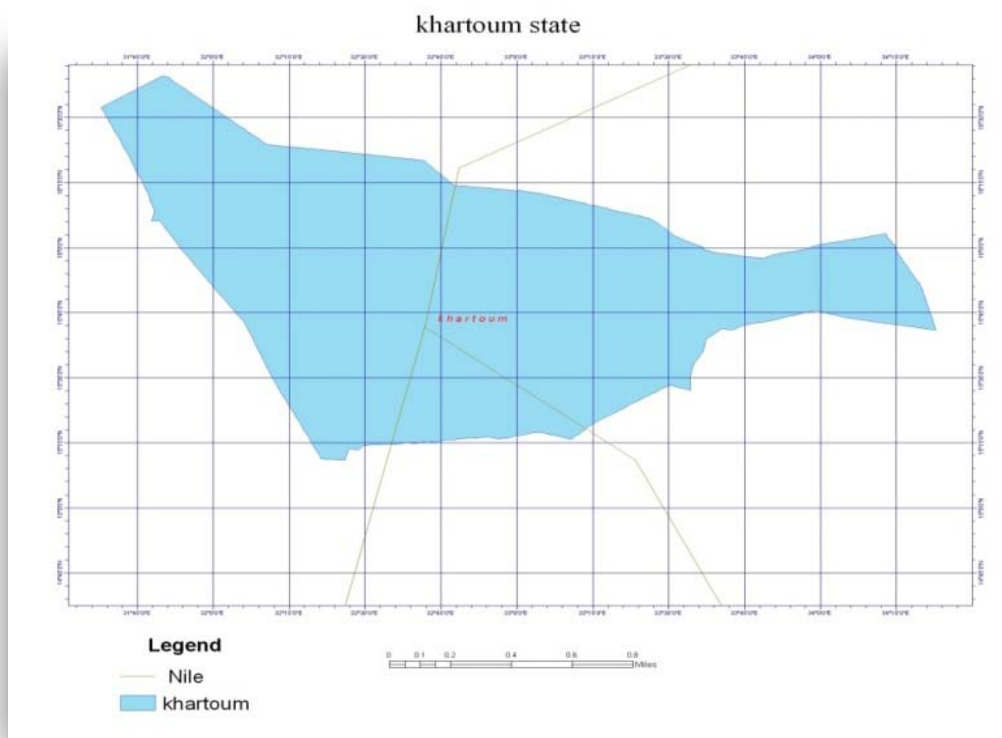

Figure 1 : The study area

ii. *Climate*

The prevailing climate is semi-desert to dry (Van der Kevie, 1973) it is hot, dry and rainy during summer and cold dry in winter. Most of the rainfall is received during July and August. The average annual rainfall is 75-160mm/year and the dry season covers 8-10 months. According to (Khartoum Metrological Station, 1998) the daily average maximum temperature 37.7C° while the daily average minimum temperature 21.6C°, maximum temperature in summer exceeds 40C°, while the minimum temperature reaches 5.2C° in winter.

The daily evaporation rate according to the (penman equation) is 7.7mm and the highest rate take place in April with average of 9.3mm. The daily mean of relative humidity is 38 at am and 21 at 2pm, while the mean wind speed is about 9 miles/hr before autumn. The area is known for its strong wind storms (Haboub) that reaches a speed of 11miles/hr.

iii. *Vegetation cover*

Vegetation cover is dominated by poor desert and semi desert type with different distribution (high density in eastern part and low density in the western part).

Generally the vegetation is dominated by some trees species of *Acacia tortilis sub sp. raddiana* (sayal), *Acacia ehrenbergiana* (salm), *Acacia nubica* (laut), *Ziziphus spina-christi* (sidir), *Acacia tortilis subsp. Tortilis* (samar),and there were some grasses and herbs included *Aristida plumosa* (Gabash), *Solanum dubium* (Jubiun), *Aristida mutabilis* (Gaw), *cenchrus biflorus* (Haskaniet) and *Cassia senna* (sena kalib).

iv. *Topography*

The topography is fairly flat but few isolated ridges and sand dunes may be observed in the western part of the site and the ground surface slopes gently to the east. The area is covered by a light brown and very thin gravely sand layer (about 10mm thick), and few angular to sub-angular, 20 to 60 mm sized fragments of ferruginous sandstone. The southern part of the site is covered by sandy gravel probably formed due to the weathering of Nubian Group rocks which are outcropping in some places in the area.

v. *Water courses*

The generally flat area of the site is confined by two wadis (shallow and relatively wide water course valleys), namely Wadi Al Howeda in the south and Wadi Al Mansourab, Shemela, Sewail in the north, which are believed to drain storm water from the upper lands of North Kordufan State into the White Nile River.

III. Methods

Field experiments were conducted during the growing season (2010) around Khartoum New International Air Port (KNIA) to investigate the effect of water harvesting techniques on growth of tree species namely (*Acaia tortilis sub sp raddiana, Acacia senegal*, and *Zizphus spina christi*). The water harvesting techniques used were: strips, pits and semi-circular.

a) Layout of the experimental field

Randomized block design with four replicates of each treatment was adopted. Each block was divided into four plots. The plot size was 20x20m.One of the four plots used as a control.

The three water harvesting techniques were designed as follows:

i. *Strips*

The land was prepared by bulldozer driven plough to make a big crescent with radius of 150m.Inside this crescent the land was divided into small strips (straight strips) by using a disc plough. The strips were 0.5m deep, 2m wide and 4m long .Each plot consisted of four trees with and in row-spacing of 3m, and the distance between strips was 4m.After the first shower the seedlings were planted in the bottom of the strips.

ii. *Semi-circles*

The land was prepared similar to the strips mention before except the land inside the big crescent was divided into semi-circles (small crescent). The small crescent was prepared by a disc plow. The crescent was 0.5m deep and of radius of 30m. The distance between the crescents was 5m. The seedlings were planted at the bottoms of the small crescent.

iii. *Pits*

The Pits were 2m deep and of radius of 2m. The Pits were prepared by a bulldozer-driven plough. The seedlings were planted in the bottom of the Pits. The Pits consisted of four trees with an in-row spacing of 2m, and the distance between the pits was 5m.

b) The planting of seedlings

After the first shower the seedlings were planted in prepared strips, pits and semi circle. Seedlings of *Acaia tortilis sub sp raddiana, Acacia senegal, Zizphus spina christi were* raised at Khartoum New International Air Port nursery.

i. *Organizing of data*

Data collected included plant variables and soil variables.

c) Plant variables

i. *Growth variables*

To monitor growth performance of the seedlings of the three trees species, number of leaves, plant shoot length and diameters of stem of seedlings were measured every three weeks from the day of the starting of the experiment.

The following variables were measured:

1- Shoot length using ruler to the nearest centimeters.
2- Diameter of seedlings using vernier caliper to the nearest millimeter.
3- Number of leafs were calculated.

d) Soil variables

i. *Soil moisture content%*

Soil samples were randomly taken from three depths, 0-30, 30-60, and 60-90cm at three locations per plot, using the auger.

Sampling was done three times during the rainy season.

Soil samples were weighed fresh, oven dried at 105C^{o} for 24 hours and reweighed.

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Soil moisture content% =

$$\frac{\text{Soil fresh mass (g) - soil oven dry mass (g)}}{\text{Oven dry mass (g)}} *100$$

e) Data analysis

Results were analyzed using SAS system. Analysis of variance (ANOVA) was made to determine the significance of variation between the species seedlings and micro catchments during the experiments period.

Duncan Multiple Range Test was used to compare mean values of various growth variables and soil moisture content in each treatment.

IV. Results and Discussion

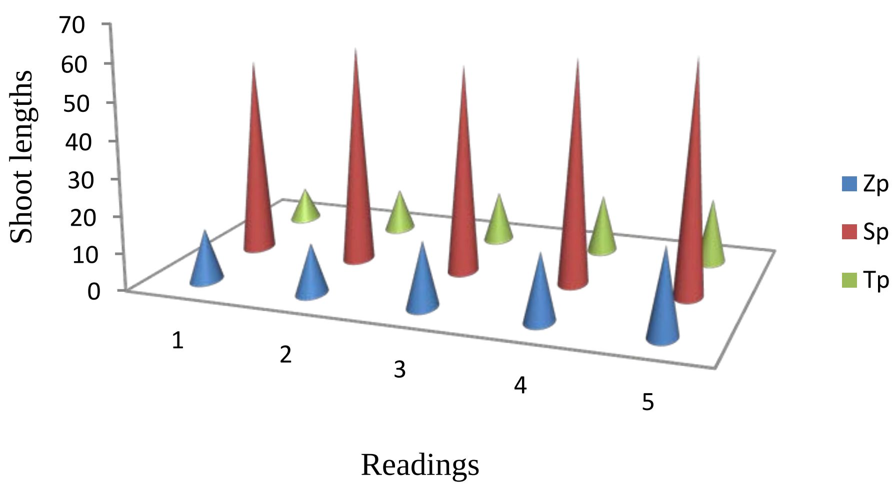
The results of this study are presented in two parts. The first part demonstrates the variations in growth rate between the species and the micro catchment used. The second part deals with the variations in soil moisture content due to micro catchment used.

After the first shower, control, and strip treatments were washed out with rain water, pits and semi-circle treatments survived.

a) The effect of micro catchments on the plant shoots length

The shoot length for the three trees species, (Figure 2), after the 1st, 2nd, 3rd, 4th, 5th readings showed no significant difference. For all the readings the best height was given by *Acacia senegal* flowed by *Ziziphus spina christi* and *Acacia tortilis subsp. raddiana.* In all the readings *Acacia senegal* and *Zizpihus spina christi* grown in the semi- circle were better than those grown in the pits. While *Acacia tortilis subsp. raddiana* showed no significant difference from the pits and semi-circle treatments. The growth of seedling and root development depend on water availability which can be achieved by micro catchment water harvesting techniques', by applying these techniques' we can enhance soil moisture storages and overcome dry spells in critical growing stages and hence secure good water for plant when rainfall is erratic.

Several studies investigate the effect of water harvesting techniques on plant growth; Gupa *et al*., (1995) investigated the effect of different water harvesting and conservation techniques. Their research indicated that the benefit of water harvesting is high and showed an 8 times increase in total biomass compared with the control plot and also proved that there was an increase in tree height by 20% and water use efficiency from 4.78 to 39.6 Kg /cm ha. Mutai (1986) reported a high survival rate for seedlings of fruit trees planted in modified semi-circle hoops in Kenya. Ojasvi *et al*., (1999) showed that *Zizyphus maurutuana* growth rates in the Jodhpur province of India were from 25-33% higher in shallow 1.0-meter.



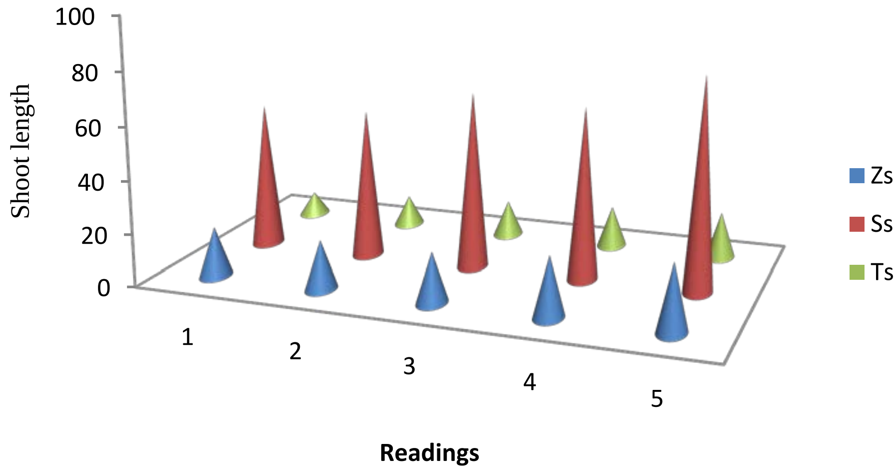


Figure 2 : Variation in shoot length between the three trees species planted in the pits and semi-circle treatment

Where: Zp: *Zizpihus spina -christi,* planted in the pits, *Sp*: *Acacia senegal,* planted in the pits, Tp: *Acacia tortilis subsp. raddiana*, planted in the pits, Zs: *Zizpihus spina -christi,* planted in the semi-circle, Ss: *Acacia senegal,* planted in the semi- circle, and Ts: *Acacia tortilis subsp. raddiana*, planted in the semi-circle.

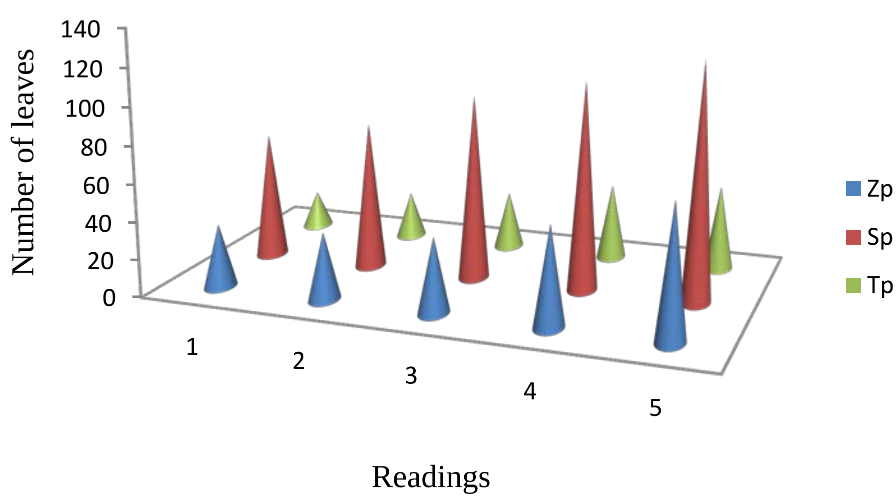
b) The effect of micro catchments on the number of leaves per plant

Plants need large quantities of water for growth, this water used during photosynthesis for producing the carbohydrates which is necessary for plant growth.

The numbers of leaves after the 1st, 2nd, 3rd, 4th, 5th readings (Figure 3) were not significantly different for the entire three tree species planted in the pits and semi-circles. The best means were given by *Acacia Senegal* planted in the pits. Number of leaves for the tree species planted in the pits was higher than those planted in the semi-circles. In this study the high growth rate of *Acacia Senegal* may be related to the fact that part of the study area situated on the gum Arabic belt which dominated by Acacia Senegal tress, and the germination of this tree occur naturally.

Leaves are important organs for photosynthesis and play an important role in survival and growth of a plant. The high water availability for plants had significantly increase leaf growth.

This result agreed with the results obtained by Sharma *et.al*. (1986). Shatanawi (1994) used rock dams, contour stone bunds, trapezoidal bunds and earth contour bunds to increase soil moisture around the trees planted on steep lands, he found that better growth was obtained by olive and almond trees. Hernandez *et al*., showed that micro catchment water harvesting increased the height and (development of canopy) number of leaves of *Psydium guajava*. The reduced growth of plants in this study concurs with the widely accepted recognition that lower soil moisture content reduces photosynthesis, growth and survivability of plants (Kozlowski et al. 1991; Condit 1998). This study supports the view that an increase in water availability results in a significantly increase in growth of plants on the basis of both plant height and new leaves.



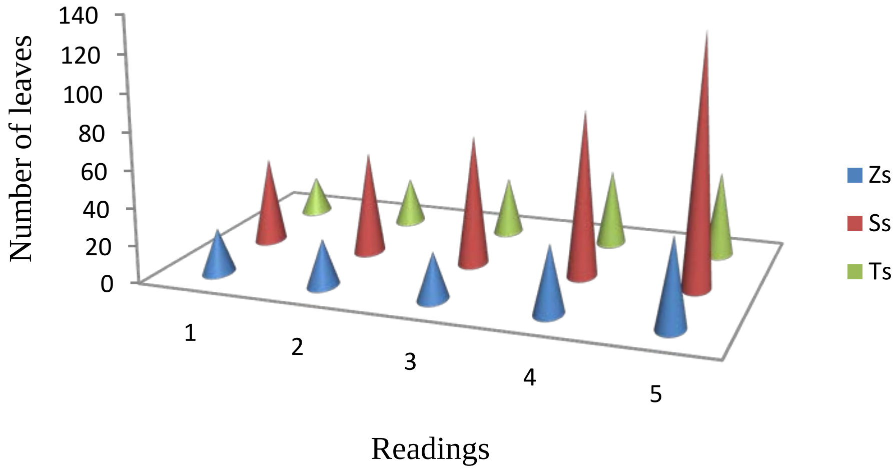


Figure 3 : Variation in number of leaves of the three trees species planted in the pits and semi circle treatments.

Where: Where: Zp: *Zizpihus spina -christi,* planted in the pits, *Sp*: *Acacia senegal,* planted in the pits, Tp: *Acacia tortilis subsp. raddiana*, planted in the pits, Zs: *Zizpihus spina -christi,* planted in the semi-circle, Ss: *Acacia senegal,* planted in the semi- circle, and Ts: *Acacia tortilis subsp. raddiana*, planted in the semi-circle.

c) The effect of micro catchments on the diameter of seedlings

The diameter of seedlings (Figure 4) the best mean was recorded by *Acacia senegal* followed by *Zizpihus spina christi* and *Acacia tortilis subsp. raddiana.* In all cases the pits were better than semi-circles catchments. . Diameter of seedlings for the tree species planted in the pits was larger than the same species planted in the semi-circles.

These results agreed with the results of Hamid (2004), and the results of Pacey and Cullis, (1986) who showed that the effective use of micro catchments water harvesting systems in growing trees and shrubs. Salih and Inanga, (1997) showed that Water harvesting techniques as contour diking proved to increase sorghum and *Acacia senegal* growth in Butana area especially for trees. Xiao-Yan Li *et al.,* (2005) showed that water harvesting treatments had a pronounced effect on the growth characteristics of *T. ramosissima*. Tree height, crown diameter and collar girth were significantly higher ($P < 0.05$) for the water harvesting treatments than the controls.

This obviously agreed with the result obtained in this study. The results of this study clearly indicated that the reforestation in this region is possible using micro catchment systems. Also this study demonstrated the potential of rain water harvesting and conservation methods in enhancing growth of trees under semi desert conditions. However, the application of various rain water methods depends on local rainfall characteristics, construction materials, site conditions, and installation methods.

Water harvesting has proved to be a valuable tool, especially in dry marginal areas to establish trees and to allow reforestation .It makes the best use of available water resources and supplements other sources.

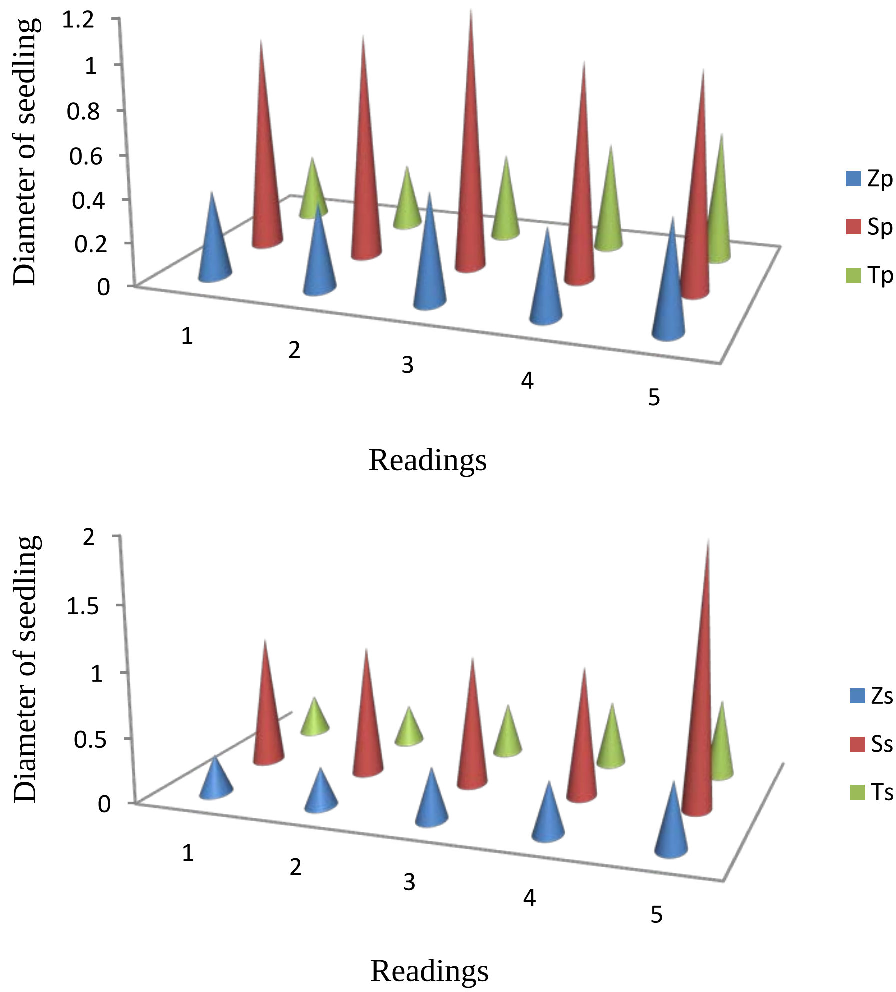


Figure 4 : Variation in diameter of seedlings for the three trees species planted in the pits and semi circle treatments.

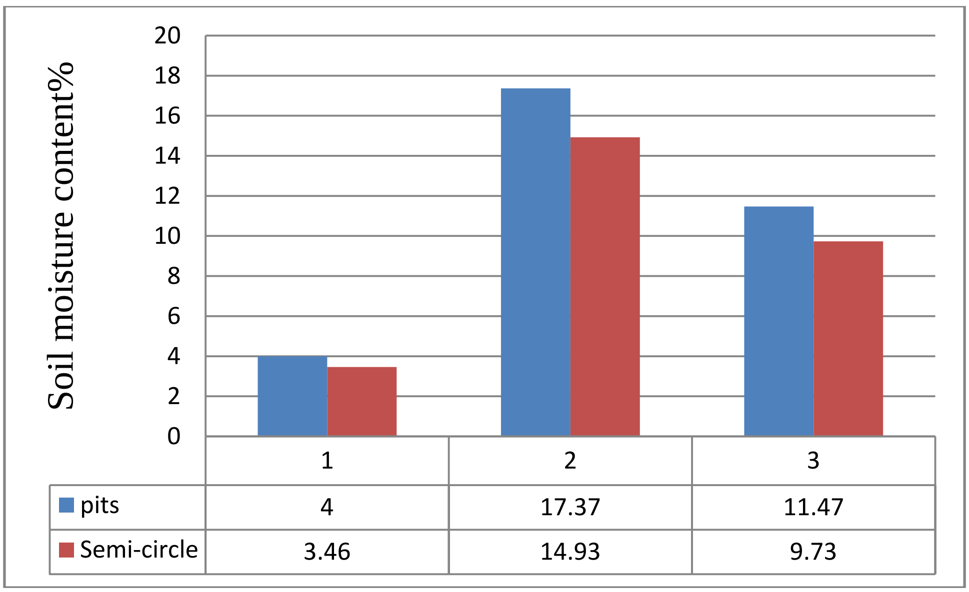
Where Where: Zp: *Zizpihus spina -christi,* planted in the pits, *Sp*: *Acacia senegal,* planted in the pits, Tp: *Acacia tortilis subsp. raddiana*, planted in the pits, Zs: *Zizpihus spina -christi,* planted in the semi-circle, Ss: *Acacia senegal,* planted in the semi- circle, and Ts: *Acacia tortilis subsp. raddiana*, planted in the semi-circle.

d) The effect of micro catchments on soil moisture content

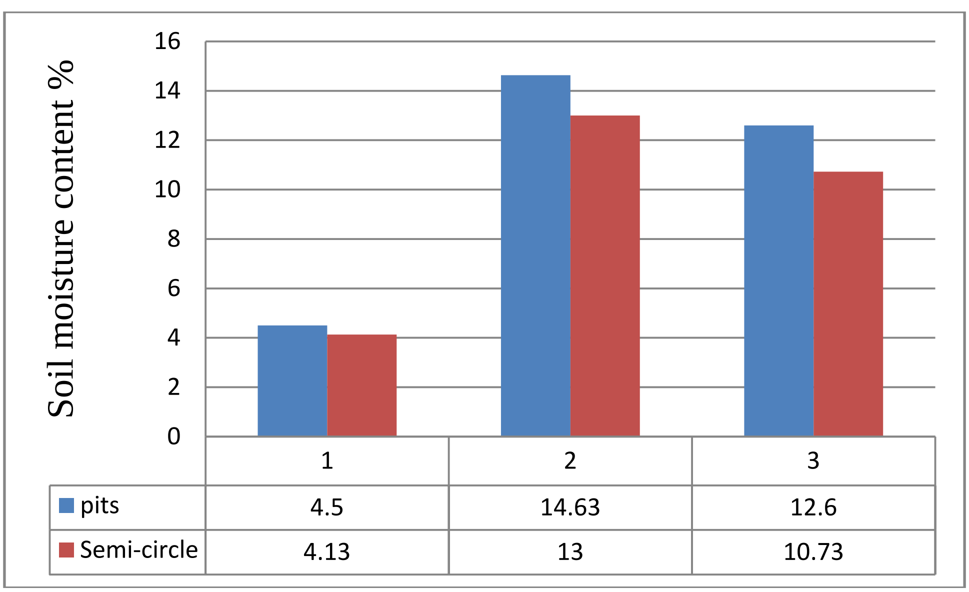
The soil moisture content (Figure 5.a, b, and c) for the 1st, 2nd, 3rd readings showed no significant difference due to type of micro catchments. The highest values were given by pits micro catchments. The effect of water harvesting on soil moisture was obvious in the middle of the rainy season, while it's low in the first and end of the rainy season. The micro catchments techniques showed to be most effective in enhancing the plant production and growth. It was also the best technique to retain soil moisture which allowed the plants to continue growing in spite of the high evaporation rates during the dry season. The reason for the low moisture content measured in this study may be related to the fact that the study area is located in the semi desert region, and the main characteristic of the climate in this region is the erratic nature of the rainfall in terms of distribution, intensity and periods of episodes. The soil moisture content closely depends on the amount of rainfall during the rainy season. This technique has proved to be a valuable tool especially in dry marginal areas to boost reforestation. Moisture stress, however, remains a major constrains. Semi-arid areas are characterized by low poorly distributed and highly variable rainfall and it is almost impossible to plant trees in these areas without some form of water management (Rocheleau *et al*., 1988). Insufficient moisture greatly hinders tree development and survival; roots are still relatively shallow and young tree cannot take advantage of deeper ground water. Of the few options available, water harvesting technology is currently the most economical means by which survival of young seedling can be enhanced (Hai, 1996).

The results of this study were agreed with the results obtained by Gupta (1995) who showed that the use of micro catchment systems in forestry plantations can significantly increase soil moisture storage, tree growth, accumulated biomass, root growth, nitrogen uptake, and phosphorous uptake over traditional planting methods. Suleman *et al.,* (1995) achieved increases in soil moisture content of 59% from 0-15cm, 63% from 15-30cm, and 80% from 30-45cm in Pakistan through the use of micro catchment systems in soils with high clay and silt contents. Moisture and its availability using water harvesting techniques proved efficient in many cases in Western Sudan, Omer and Eltighani, (1997) used different tillage systems and found that it resulted in improved soil physical properties pertaining to water conservation. Aldon and Springfield, (1975); Boers and Ben-Asher, (1982); Sharma *et al*., (1986); Brooks *et al.,* (1991) who reported that micro catchments water harvesting techniques can be successful in years of normal or above normal rainfall and are best suited for situations in which drought-resistant trees or other drought hardy perennial species are grown.

A-for soil depth 0-30cm



B for soil depth 30-60cm



C for soil depth 60-90cm

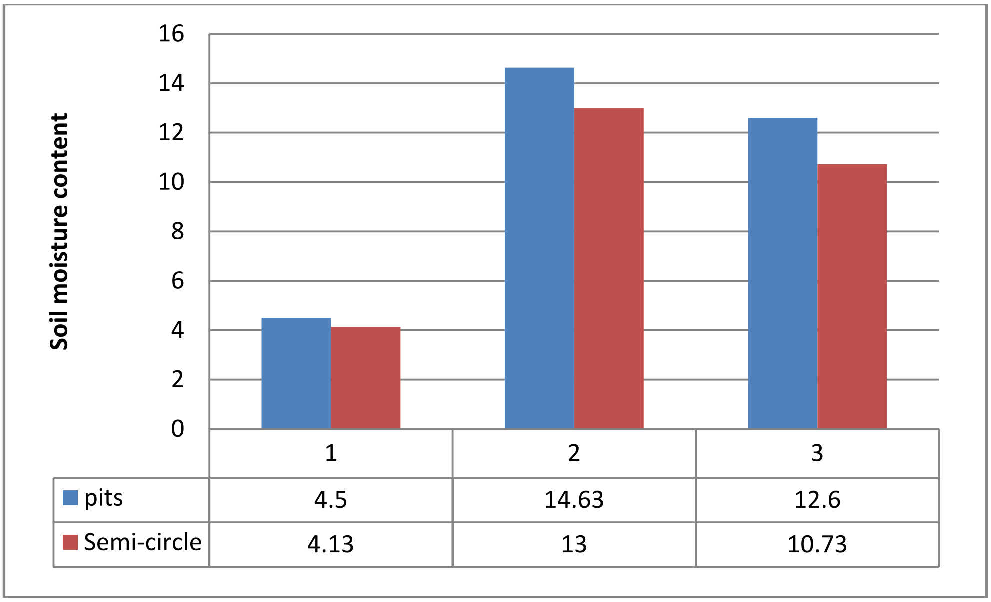


Figure 5 : Variance Analysis of the soil moisture content for the pits and semi-circles of different depth (cm)

V. Conclusions

The results of this study revealed that pits water harvesting techniques method proved to be more effective in enhancing soil moisture and produced better growth of the trees species studied.

The growth variables of the three species planted in the pits is better than semi circle.

The soil moisture content is higher in the pits than in the semi circle.

The pits water harvesting technique showed to be the most effective in enhancing the trees growth. It was also the best technique to retain soil moisture which allowed the trees to continue growing in spite of the high evaporation rates during the dry season.

The pits method shows great promise in increasing tree establishment rates. This method can greatly aid trees through helping to harvest rainwater and protecting them.

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