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Comparison between Cocoon and other Water Harvesting Techniques on Growth Parameters of *Acacia seyal* seedlings Planted in Cracking Clay Plains, White Nile State, Sudan.

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Abstract

The study was conducted at Almakhaleef nursery at Aj'Jebelain locality which lies on the Eastern bank of the White Nile River in Southern part of White Nile State of Sudan (12º 10' N Latitude, 34º 05' E Longitude), and 60 Km from Rabak city, the capital of the State. The experiment was conducted for one rainy season (2021). The study site lies in the low rainfall woodland savannah region. The average minimum and maximum temperatures were 30°C and 42°C, respectively. The mean annual rainfall of the study area is 350 mm. The soil is cracking of alluvial origin. Soil pH values range from 8.0 to 9.5, fine textures of 60% clay fraction and relative thickness. The main objective of this study was to compare Cocoon Technology with other water harvesting techniques for the seedling growth parameters of *Acacia seyal*. The experiment was layed out in a Randomized Complete Block Design (RCBD) with three blocks. The treatment consisted of three types of water harvesting techniques (Cocoon, Crescent-shape "Dome Lune" and Traditional planting on flat land without terracing as control) as subplot treatments and two watering regimes ("rain water + irrigation" & rain water) as main plot treatments in three replicates (Blocks). Healthy *Acacia seyal* seedlings were planted. The shoot height, stem diameter at root collar and number of branches were measured every four weeks after transplanting. Soil moisture content measured at the study site from five consecutive pits, measurements were taken at two depth levels (25cm and 50cm) by using a thermo-hygrometer sensor to determine the amount of relative humidity in the soil. Results of Analysis of Variance obtained showed that the effect of all water harvesting techniques under both conditions of ("rain water + irrigation" and "rain water") on shoot height, stem diameter at root collar and number of branches had resulted in improvement in growth parameters, and the statistical significant test result at ($p \leq 0.05$) revealed there was no significant differences among the treatment means with respect to the growth performance of seedlings of A. seyal in terms of shoot height, stem diameter at root collar and number of branches development under both conditions of "rain + irrigation" and "rain water", which means the Null hypothesis to be rejected and that the effect of Cocoon, Crescent-shape and flat traditional water harvesting techniques on growth performance showed small variation in values, and the best measurements for the different parameters were recorded in some sample plots.

Keywords: Low Rainfall Woodland Savannah, Clay Soils, Water harvesting techniques, Growth parameters, Moisture content.

Introduction

Talih (*Acacia seyal*) is a very important tree species for the versatile uses of its wood, leaves and flowers fodder for animals, protects and enriches the soil (Nitrogen Fixation). Acacia seyal is the tree number one in Sudan whose promising potential has never been fully explored (Abdel Nour, 2008). A. seyal is attributed to being a multi-purpose tree that produces excellent fuel wood, charcoal, animal fodder. It is estimated that 70% of Sudanese energy budget is from fuel wood that mostly comes from A. seyal (FNC, 1995). Another important aspect is its role as a gum producing source. Gum is profusely produced from the tree (gum talha) but was given less attention in the country in the past. This gum is mostly obtained from natural stands and through natural exudation (Abdel Nour, 1999; Seif el Din and Zarroug, 1998). It occurs in association with Balanitesaegyptiaca in the low rainfall woodland with grass on the clay plains of central Sudan, where the annual rainfall ranges from 500 to 800 mm. The species is an important source of fuel wood, building poles, forage, commercial gums, and tannins (Elamin, 1990; Mustafa, 1997; Maydell, 1990; Wickens et al., 1995) and is a source of nectar for honeybees (Booth and Wickens, 1988). A. seyal produces gum which though of inferior quality in comparison to that of Acacia senegal, is traded in Sudan under the name "gum talha" and makes up to 10 percent of the annual exported gum Arabic (McAllan, 1993; NFTA, 1994). Unlike gum from A. senegal, gum talha is not recognized as an acceptable food additive. Additionally, A. seyal serves valuable ecological functions such as reducing soil erosion and acting as a defence line for desert encroachment in many parts of the Sudan . The species thrives in most soil types, even in heavy clay and stony soils found on the plains. It often grows with other tree species, such as *Acacia sieberana*, *Anogeissusleiocarpus*, *Balanitesaegyptiaca*, *Faidherbiaalbida* and *Ziziphusmauritiana* (ibid). The species is distributed throughout its natural range, and is usually associated with Balanitesaegyptiaca in the Acacia seyal-Balanites woodland area. In such formation, A. seyal is the dominant species, forming pure dense stands in many areas. According to Mustafa (1997), this formation begins to emerge with an increase in the annual rainfall to accumulations of more than 500 mm. In the savanna region of Sudan, A. seyal has been subjected to large-scale clearing for mechanized agriculture (Mustafa, 1997; Vink, 1990; Wickens*et al*., 1995), associated with firewood and charcoal production to meet energy requirements. Besides clearance for mechanized farming and wood fuel, other factors such as grazing, deliberate and undeliberate fires also have a significant negative impact, not only on natural stands of A. seyal but also on natural forests in Sudan. Proper forest management is currently in minimal level for A. seyal including both establishment and harvesting. FNC, however, established A. seyal plantations by seedlings and seeds in several reserved forests. The seeds of A. seyal. var. seyal are difficult to collect albeit being locally dispersed in large amounts by different agents e.g. have been found deposited in animal feces along transhumance routes (ICRAF, 2009). However established plantations proved costly due to many required operations such as raising of seedlings, transportation, flying nurseries, land ploughing, planting out and other various activities. Sprouting from stumps is generally undependable.

Material and Methods

Seeds of A. seyal collected from the study area. Hundred healthy seeds were treated by (98%) Sulphuric Acid for five minutes and then germinated on moist filter paper placed into Petri dishes and watered regularly with distilled water. The seeds that produced a 1-mm radicle were considered germinable, viability counted as 95%. Black polythene bags of 10 cm diameter and 20 cm length were filled with well-prepared potting media; a mixture of two-thirds silt soil and one-third sandy soil. Then placed into seed beds and planted with A. seyal seeds. Seedlings were raised in the nursery for five months, then transplanted. A factorial experiment was designed in randomized complete block design (RCBD) with three blocks. The treatment consisted of three types of water harvesting techniques (Cocoon, Crescent-shape "Dome Lune" and Traditional planting on flat land without terracing as control) as subplot treatments and two watering regimes ("rain water + irrigation" & rain water) as main plot treatments in three replicates (Blocks). Total area of experiment was 0.3 hectare, each block was 82 m x 12 m, blocks separated 2 m apart. Plot size was 12m x12m, plots were also separated 2 m apart. Seedlings were planted at Space 3m x 2m, the total number of seedlings planted were 360 healthy A. seyal seedlings. Data on shoot height, Diameter at Root Collar, number of branches were measured from all treatments, averagely calculated and subjected to analysis of variance in Randomized Complete Block Design (RCBD) to compare the effect of cocoon techniques with other water harvesting techniques on development of Shoot height, number of branches, stem diameter at root collar of A. seyal seedlings planted in cracking clay soil at Aj'Jebelain locality. Measurements on these parameters were done immediately after planting in July 2021, and then every month till November 2021. Shoot height was measured from the surface of the soil to the highest tip of seedlings using a millimeter graduated glass ruler. Root collar diameter was measured on the girth of the seedlings immediately after the surface of the soil using a vernier caliper. Moisture content readings were taken at two depth levels of 25cm and 50 cm from the 5 consecutive locations respectively, averagely calculated for each level and compared to the respective level's readings to find out whether there was significant differences between the different readings of each level or not.All the data were statistically analyzed using electronic statistical calculator. ANOVA was performed to detect the difference between treatment means, and to compare means using coefficient of variation to detect the level of precision in the field experiment. Mean differences were considered significant when $p \leq 0.05$.

Results

Effect of water harvesting (WH) treatment on shoot height

Table 1. Mean Shoot height (cm) of seedlings in plots of Acacia seyal planted under "rain water + irrigation", in field experiment laid out under RCBD. Data are given after root transformation.

Source of Variation	df	SS	MS	F-value	p-value
Replication	2	2.22	1.11	5.05	0.0806
Treatment	2	0.78	0.39	1.772	0.2810
Error	4	0.88	0.22		
Total	8	3.88			

The statistically significant test result at ($p \leq 0.05$) revealed that there was no significant differences among the treatment means with respect to the growth in terms of shoot height development under "rain water + irrigation". The best height of A. seyal seedlings was recorded by the cocoon and crescent-shaped sample plots in replication one; therefore, the Null hypothesis will be rejected. On the other hand the relatively low value of coefficient of variation (*cv*=%5.61) indicated the reasonable level of precision attained in the field experiment.

Table 2. Mean Shoot height (cm) of seedlings in plots of Acacia seyal planted under "rain water", in field experiment laid out under RCBD. Data given after root transformation.

Source of Variation	df	SS	MS	F-value	p-value
Replication	2	0.64	0.32	0.59	0.5947
Treatment	2	1.98	0.99	1.83	0.2733
Error	4	2.16	0.54		
Total	**8**	**4.78**			

The statistically significant test result at ($p \leq 0.05$) revealed there was no significant differences among the treatment means with respect to the growth in terms of shoot height development under "rain water". The best height of A. seyal seedlings was recorded for the cocoon sample plot in replication three; therefore, the Null hypothesis will be rejected. On the other hand the relatively low value of coefficient of variation (cv=%9.62) indicated the reasonable level of precision attained in the field experiment.

Table 3. Mean Stem Diameter (cm) of seedlings in plots of Acacia seyal planted under "rain water + irrigation", in field experiment laid out under RCBD.

Source of Variation	df	SS	MS	F-value	p-value
Replication	2	0.01	0.00	0.89	0.4781
Treatment	2	0.03	0.01	2.87	0.1690
Error	4	0.02	0.00		
Total	**8**	**0.06**			

The statistically significant test result at ($p \leq 0.05$) revealed there was no significant differences among the treatment means with respect to the growth in terms of stem diameter development under "rain water + irrigation". The best diameter of A. seyal seedlings was recorded by the crescent-shaped sample plot in replication three; therefore, the Null hypothesis will be rejected. On the other hand the relatively low value of coefficient of variation (cv=%9.83) indicated the reasonable level of precision attained in the field experiment.

Table 4. Mean Stem Diameter (cm) of seedlings in plots of Acacia seyal planted under "rain water ", in field experiment laid out under RCBD.

Source of Variation	df	SS	MS	F-value	p-value
Replication	2	0.01	0.00	0.89	0.4781
Treatment	2	0.03	0.01	2.87	0.1690
Error	4	0.02	0.00		
Total	**8**	**0.06**			

The statistically significant test result at ($p \leq 0.05$) revealed there was no significant differences among the treatment means with respect to the growth in terms of stem diameter development under "rain water ". The best height of A. seyal seedlings was recorded for the crescent-shaped and traditional sample plots in replication two; therefore, the Null hypothesis will be rejected. On the other hand the relatively low value of coefficient of variation (cv=%11.21) indicated the reasonable level of precision attained in the field experiment.

Table 5. Mean number of branches of seedlings in plots of Acacia seyal planted under "rain water + irrigation", in field experiment laid out under RCBD

Source of Variation	df	SS	MS	F-value	p-value
Replication	2	1.34	0.67	1.82	0.2743
Treatment	2	3.93	1.965	5.33	0.0744
Error	4	1.47	0.37		
Total	**8**	**6.74**			

The statistically significant test result at ($p \leq 0.05$) revealed there was no significant differences among the treatment means with respect to the growth in terms of number of branches development under "rain water + irrigation". The best number of branches of A. seyal seedlings was recorded by the traditional sample plot in replication one; therefore, the Null hypothesis will be rejected. On the other hand the relatively low value of coefficient of variation (cv=%11.38) indicated the reasonable level of precision attained in the field experiment.

Table 6. Mean number of branches of seedlings in plots of Acacia seyal planted under "rain water", in field experiment laid out under RCBD.

Source of Variation	df	SS	MS	F-value	p-value
Replication	2	0.35	0.17	٠.٢٩	0.7632
Treatment	2	2.84	1.42	٢.36	0.2107
Error	4	2.41	0.60		
Total	**8**	**5.60**			

The statistically significant test result at ($p \le 0.05$) revealed there was no significant differences among the treatment means with respect to the growth in terms of number of branches development under "rain water". The best number of branches of A. seyal seedlings was recorded by the traditional sample plot in replication one, and the crescent-shaped sample plot in replication three; therefore, the Null hypothesis will be rejected. On the other hand the relatively low value of coefficient of variation (cv=%14.80) indicated the reasonable level of precision attained in the field experiment.

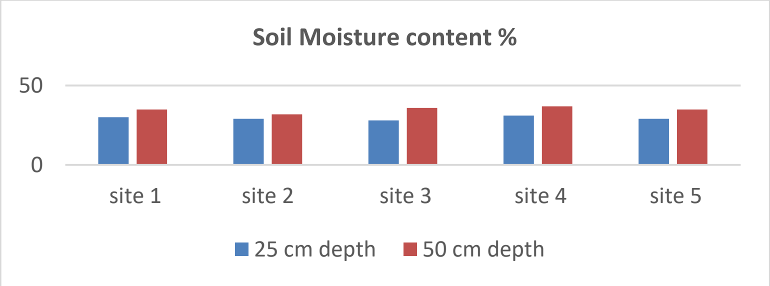
Soil Moisture Content

Data obtained were averaged, and mean total was calculated. Results showed that there were no significant differences between the percentage of moisture content of the five sites at both depths when compared with the mean totals.

Table 7. Soil Moisture Percentage at Study Site

Depth Level/ cm	Soil Moisture % at the Five Locations					Mean
	1	2	3	4	5	
25	30	29	28	31	29	29.4
50	35	32	36	37	35	35.0

Fig.(1): soil moisture content % at the selected sites



Discussion

In the present study the micro-catchment of water harvesting techniques of various types and shapes were used to evaluate their effect on growth and development of seedlings of A. seyal. Results obtained showed that the effect of all water harvesting techniques under both conditions (subplots of "rain water + irrigation" and "rain water") on shoot height, stem diameter at root collar and number of branches were more or less the same overall treatments and there was no significant differences among treatments means which were observed. However, YousifSuliman (2006) found that the effect of water harvesting on growth and development of Almond spp., increased the leaf area, shoot length, shoot number, stem diameter and plant height. While G. Singh et al., (2013) indicated the improvement of the micro-climate as a result of usage of water harvesting techniques had been improved, which resulted in improvement of plant growth in India. Results obtained by M. Mureithi et al., (2018) revealed the plant growth parameters were increased by water conservation method for most attributes studied and there was no significance difference between contour ridge and rain fed treatment. The results agreed with Sona M. Mohamed et al., (2016) who indicated that the higher mean diameter of seedlings of Acacia senegal followed by Ziziphusspina-christi and Acacia tortillas 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 also agreed with 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 Butane area especially for trees. Xiao-Yan Li et al., (2005) revealed that water harvesting treatments had a pronounced effect on the growth characteristics of tree height, crown diameter and collar girth were significantly higher 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 dry conditions. However, the application of various rain water methods depends on local rainfall characteristics, site conditions, and conservation methods used to make the best use of available water resources. The result of the soil moisture experiment agreed with the study conducted by Elias et al., (2001) who stated that cracks lead to loss of soil moisture rapidly at the upper soil level through evaporation, lead to failure of regeneration of vegetation, which indicated the importance of usage of soil and water conservation structures for the success and sustainability of reforestation activities in dryland areas.

Conclusion

Water harvesting is a methodology that has been used worldwide to concentrate, collect, and distribute water that normally would be inaccessible for applications in irrigated agriculture, individual domestic water supply, forest and rangeland management. Water harvesting has proved to be a valuable tool, especially in dry marginal areas, to establish tree crops and to allow afforestation 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. In this study various water harvesting techniques were tested for development of A. seyal growth parameters. It makes best use of available water resources and supplements the other sources. The current study aimed to compare the effect of cocoon technology with other water harvesting techniques on the development of seedlings of A, seyal. The effect of the water-harvesting techniques; the groasis grow box "cocoon", crescent-shape and traditional flat micro-catchments was studied on development of growth parameters of A. seyal (shoot height, stem diameter at root collar and number of branches. The results showed that in all treatments tested there was no significant differences among treatment means, the result proved that the three types of water harvesting techniques more or less had the same effect on the growth parameters of A. seyal seedlings in clay soils of central Sudan. It is also noted that the cost of cocoon is higher and the cocoon technology is unsuitable for the specific conditions of the study site; although each water harvesting technique has its advantages and limitations which need to be evaluated.

Recommendations

More emphasis should be given to water harvesting in areas affected by drought to enhance regeneration and management of the degraded natural forest lands.

The findings of this study present new perspectives for future research in order to promote the development of Acacia seyal and other tree species in dry lands. For the future development of research the following suggestions are made:

1. Further investigations and experimentation in water harvesting techniques for reforestation activities.
2. Permanent plots at different climatic regions of Sudan could be selected to investigate about the interaction of water harvesting techniques and tree species development.
3. Evaluation of advantages and disadvantages of various water harvesting techniques is highly recommended.

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