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Evaluation the Effects of Water Harvesting Techniques in Improving Water Conservation and Increasing Crop Yields

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***Abstract*-**Effects of five water harvesting techniques (mulching, intercropping, stone barriers, crescent and L-shaped earth bund) and control on soil water status, and sorghum (Sorghum bicolor L.) plant performance were investigated. The moisture content of the soil was measured at three periods (before crop sowing, at mid-season and after harvest) and at four depths (0-15, 15-30, 30-60 and 60-90 cm). Each technique was replicated four times in a factorial arrangement. The results of this study showed that the soil and plant parameters were significantly influenced by the water harvesting techniques during both growing seasons through improving the structure, infiltrability and water storage capacity of the soil over control. The variability of soil moisture content and plant parameters increased during the drier season and decreased during the wetter season. Soil depth measurement period and their interaction had highly significance effects on soil moisture content during both growing seasons. Differences among the water harvesting techniques were more pronounced in the topsoil layer (0-30 cm) with no appreciable differences below 30 cm depth. Straw mulching conserved more moisture within one profile, particularly at the medium and lower depths (30-90cm). It also consistently retained more run-off water than the other techniques at all stages of plant growth in both growing seasons followed by earth and stone bund. This was clearly reflected by the better establishment and yield components of sorghum, hence greater gross returns. However, mulching was less effective for prolonged periods when the surface of the soil was dry. Crescent-shaped earth bund treatment ranked second to mulching in moisture storage and plant parameters. It showed no significantly from stone barriers in water storage and crop performance. On the other hand, control treatment produced the lowest moisture values followed by intercropping and stone barriers, which were more profitable compared to the other techniques in both growing seasons. However, the relative advantages of intercropping were less under conditions of severe water stress.

Keywords- *Harvesting, Intercropping, Soil, Sorghum, Variability, Water*

I. INTRODUCTION

Soil and water, which are the basic factors in crop production, are becoming major problems all over the world. Millions of hectares are degrading and declining in productivity, as a result of erosion, moisture deficit and loss of fertility. The problem is more severely in the arid and semi-arid areas, where the problems of environmental degradation, drought and population pressure are most evident. Sloping lands are particularly vulnerable to erosion and moisture deficit. The study area is characterized by sloping land, presence of various valleys and seasonal watercourses, which are usually poorly managed. Hence, erosion occurs resulting in loss of the valuable topsoil and is always accompanied by greater losses in surface runoff. The meteorological data from meteorological stations in the study areas showed marked variation and poor distribution of rainfall during the last three decades. The mean annual rainfall had declined from more than 700 mm during the period between the mid 40's and the mid 50's to less than 500 mm during the 80's and early 90's [1]. Such fluctuations may have negative implications on water resources and agricultural production. This urges maximum utilization of rainwater for crop production through different conservation measures. The traditional conservation measures may be replaced or improved. In order to be more effective, economically, viable, easily acceptable and adaptable. The measures must be capable of achieving of flowing objectives:

- Optimizing the use of run- off water on sloping lands and checking erosion risks through different conservation measures.
- Evaluating the effects of five water harvesting techniques in improving water conservation and increasing and stabilizing crop yield.
- Utilizing the small farmer holding most economically (viz: replacing mono cropping by mixed cropping).
- Providing alternative means of soil water conservation to be adopted by farmers.

II. MATERIALS AND METHODS

The experimental site lies within a semi- arid savannah zone of 584.4 mm and mean air temperature of 24-26^{o} C. Soils are gently sloping (1-3%). The predominant topsoil is loam, becoming loam or clay depth.

The experiment was conducted in the 2000-01 and 2001-02 growing seasons, following a factorial experimental design with four replications. The experiment consisted of five water harvesting techniques plus control 24 plots (4 m× 30 m each) were laid out with spacing of 2 m between plots, while 4 m between replications were kept as buffer zones. The borders of each plot were raised to prevent runoff.

Water harvesting techniques were:

T_o= no conservation measures.

T_1= mulching with millet straw at 4.2 t/ha in bands (45 cm wide and 25 cm apart) providing 63% surface cover. Sorghum grains were hand sown in rows between the bands.

T_2= intercropping local cultivars of sorghum, *Sorghum bicolor* L.(Cv. Fasiekh, Sibyan Sawa) with groundnut , *Arachis hypogaea* (Cv. Sodari) in a 1:1 row ration.

T_3= simple stone barriers (stones with 10-30 cm in diameter were placed along the contour at horizontal intervals of 10 m across the slope. The stones were set into 5 cm deep and 30 cm wide furrows, forming 25 cm high bunds).

T_4 and T_5= crescent – shaped (T_4) and L-shaped (T_5) earth bunds were constructed across the slope with their arm tips lying on the contour and a shallow furrow at the up slope side. The bunds (40 cm base width 15 cm top width and 30 cm height) were spaced at 10 m horizontal intervals down the slope. They were provided with 40 cm wide and 15 cm high outlet at opposite sides of successive bunds.

In all techniques, sorghum was planted flat on rows at a seed rate of 9 kg/ha, 5-7 grains/hill thinned to three plants/hill after three weeks from sowing. In the intercropping technique, groundnut was sown manually at rate of 60 kg/ha with 2 seeds /hill. Sole groundnut was included in additional rows for yield comparison.

Intera and interrow-spacing of 70 and 40 cm were allowed respectively, for monocropped and intercropped sorghum, whereas 70 and 25 cm spacing were provided respectively for monocropped and intercropped groundnut. Crops were sown on 7^{th} July 2000 and 21^{th} July 2001.

No fertilizers were applied and two times of hoe-weeding were done at 25 and 45 days after sowing in both growing seasons.

Plant height at 14-day intervals, number of tillers/ plant and the percentage of plants producing heads were recorded from 20 randomly selected plants from each plot. Immediately after harvesting the ear heads, the plants from the center 20 m^2 (2 m × 10 m) of each plot area were cut at ground level and weighed for fresh matter weight determination. The same plants were air-dried for three weeks and weighed for dry matter determination. Final harvests for grain were taken from the whole plot area on the 17^{th} of November (132 days after sowing) and 24^{th} of October (95 days after sowing) in the first and second seasons, respectively. Groundnut plants were uprooted 91 and 95 days after sowing in the first and second season, respectively, and the total pod yields were determined.

III. Results

In all studied areas the soil moisture content was higher in the 2^{nd} growing season (Table 1). The results in (Table 2 and 3) showed significant differences ($p \leq 0.01$) in soil moisture reserves under the different water harvesting techniques for all plant growth stages and measurement periods during both growing seasons. T_1 consistently retained more runoff water (Table 4) and produced the highest moisture content than the other techniques, in both seasons followed by T_3 and T_2 particularly at the initial and development stages (Table 3). There were no significant differences between T_1 and $T_{4,}$ and between T_3 and T_5 at the three measurement periods. T_4 ranked second to T_1 in moisture conservation, although T_4 gave more moisture at upper layers (0-15 cm) immediately above the bunds, which was reflected by the good crop performance and yield. On the other hand T_1 stored more water in the medium and lower layers of the soil (30-90cm).

Measurement period and its interaction with water harvesting and soil depth were highly significant ($p \leq 0.01$) during both growing seasons (Table 2). The mean total moisture values at the three periods differed significantly from each other with mid-season showed the greatest values (10.8% and 13.5% and before treatment application the lowest values (5.94% and 6.52%) in the first and second season, respectively (Figure 1).

In the middle of both seasons soil moisture was in the order $T_1 > T_4 > T_5 > T_3 > T_2 > T_0$. Soil depth was also highly significant ($p \leq 0.01$) in both growing seasons, while its interaction with water harvesting technique was highly significant in the second season only (Table 5). For all techniques, average soil moisture content tended to increase with increasing soil depth and differences among water harvesting techniques were more pronounced in the top soil layer (0-15 cm) then decreased at lower layers (between 30 cm depth) (Figure 2).

The main effects of water harvesting technique and soil depth were also highly significant ($p \leq 0.05$) for all growth stages during both seasons (Table 5). Soil moisture content was maximum in all plots treated with straw mulch at the various growth stages and soil depths.

T_1 increased soil water storage by 29.1, 35.8, 30.1 and 22.4% in the first cropping season and by 29.5, 24.9, 20.2 and 26.2% in the second season during the initial, development, mid- season and late season stages, respectively, as compared to T_0 and T_2 differed slightly, lent significantly in moisture content from T_0 at initial growth stages and their differences increased with time throughout the growing season with improved intercrop canopy cover. Moisture content also increased with increasing soil depth to maximum value at 15-30 cm depth and then decreased but all techniques accumulated water in the lower layers with time (Figures 3a and 3b).

Data of plant variables are presented in (Table 6). The two sorghum cultivars respond in the same way to water harvesting techniques even though their individual heights and maturity periods differed. The second season showed better results than first season for all treatments. On the other hand, all sorghum variables were significantly affected ($p \leq 0.01$) by the water harvesting technique. The influence of water harvesting technique was consisted with the conserved moisture in the soil profile. T_1 consistently resulted in better plant performance and gross returns during both growing seasons, although did not significantly difference from bunded plots, which did not differed from each other in most cases T_4 ranked second to T_1 in all plant variables. On the other hand, T_0 resulted in the poorest plant performance, particularly in the first season, although did not significantly differed from T_2.

TABLE I. AVERAGE VALUES OF SOIL MOISTURE CONTENT (V/V) AS INFLUENCED BY SLOPE GRADIENT WATER HARVESTING TECHNIQUE, SOIL DEPTH AND MEASUREMENT PERIOD

Treatment	Season (1)			Mean	Season (2)			Mean
	Area 1	Area 2	Area 3		Area 1	Area 2	Area 3	
Water Harvesting Technique								
±0.084 ±0.048					±0.117 ±0.067			
T_0	8.30	8.22	8.20	8.24^{c}	9.86	9.81	9.69	9.79^{d}
T_1	9.14	9.15	9.00	9.09^{a}	10.87	10.80	10.95	10.87^{a}
T_2	8.37	8.35	8.42	8.38^{c}	10.24	10.35	10.33	10.31^{c}
T_3	8.79	8.74	8.76	8.76^{b}	10.63	10.66	10.50	10.60^{b}
T_4	9.03	9.09	9.09	9.07^{a}	10.96	10.87	10.71	10.85^{a}
T_5	8.90	8.92	8.96	8.92^{b}	10.78	10.71	10.71	10.74^{ab}
±0.034					±0.048			
Mean	9.76^{d}	8.74^{d}	8.74^{d}		10.56^{c}	10.58^{c}	10.49^{c}	
Soil Depth (cm)								
±0.068 ±0.039					±0.095 ±0.055			
0-15	5.01	5.01	4.98	5.00^{d}	7.03	7.01	6.93	6.99^{d}
15-30	7.93	7.90	7.88	7.90^{c}	10.78	10.74	10.76	10.76^{c}
30-60	10.55	10.57	10.58	10.57^{b}	12.12	12.09	12.01	12.07^{b}
60-90	11.53	11.50	11.52	11.52^{a}	12.30	12.20	12.24	12.28^{a}
Mean	8.76^{c}	8.74^{c}	8.74^{c}		10.56^{c}	10.50^{c}	10.49^{c}	
Measurement Period (P)								
±0.0 ±0.034					±0.083 ±0.048			
Before Sowing	5.98	5.90	6.93	5.94^{c}	6.55	6.50	6.50	6.52^{c}
Mid-Season	10.71	10.80	10.77	10.78^{a}	13.52	13.54	13.43	13.30^{a}
After Harvesting	9.52	9.53	8.52	9.52^{b}	11.60	11.56	11.53	11.50^{b}
±0.034					±0.048			
Mean	8.76^{d}	8.74^{d}	8.74^{d}		10.56^{d}	10.53^{d}	10.49^{d}	
C.V. (%)	6.63				7.68			

For each growing season, means followed by the same letter(s) are not significantly different at 5% level according to DMRT.

TABLE II. ANALYSIS OF VARIANCE FOR SOIL MOISTURE CONTENT AT FOUR CROP GROWTH STAGES DURING THE TWO SEASONS

Source of variation	D. F	Mean Squares (ms)							
		Initial stage		Development stage		Mid-season stage		Final stage	
		Season 1	Season 2	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2
Replication	9	0.3359 NS	0.1376 NS	0.1521 NS	0.1461 NS	0.3696 NS	0.1474 NS	0.1991 NS	0.1968 NS
Slope (S)	2	0.6442 NS	0.839 NS	0.7896 NS	0.8451 NS	0.2694 NS	0.6924 NS	0.2023 NS	0.3995 NS
Technique (T)	5	75.217**	74.448**	91.2376**	80.596**	77.305**	61.639**	16.0354**	80.946**
Depth (D)	3	1091.802**	666.601**	374.115**	845.442**	363.999**	530.326**	655.798**	94.093**
S x T	10	0.744 NS	0.6014 NS	1.3182 NS	0.9119 NS	0.7702 NS	0.2933 NS	0.7583 NS	0.5548 NS
S x D	6	0.963 NS	0.0446 NS	0.5756 NS	0.3802 NS	0.332 NS	0.1813 NS	0.3452 NS	0.1711 NS
T x D	15	5.9069**	3.2412*	2.4525*	1.7852 NS	5.026**	1.4521 NS	2.5377 NS	3.8533**
S x T x D	30	0.1277 NS	0.2939 NS	0.1981 NS	0.3938 NS	0.4787 NS	0.4483 NS	0.3675 NS	0.2556 NS
Error	207	0.8174	0.8919	1.4124	2.0656	0.5567	1.8950	1.2933	0.9030
Total	287								

NS: Not significant
*: Significant at $P \leq 0.05$
**: Significant at $P \leq 0.01$

TABLE III. AVERAGE VALUES OF SOIL MOISTURE CONTENT (V/V) AS INFLUENCED BY WATER HARVESTING TECHNIQUE, SOIL DEPTH & MEASUREMENT PERIOD

Treatment	Season 1				Season 2			
	P_1	P_2	P_3	Mean	P_1	P_2	P_3	Mean
Water harvesting technique								
	±0.084		±0.048			±0.117	±0.067	
T_0	5.95^{n}	9.82^{k}	8.95^{m}	8.24^{c}	6.28^{r}	12.40^{l}	10.67^{p}	9.79^{d}
T_1	5.97^{n}	11.42^{g}	9.89^{k}	9.09^{a}	6.38^{qr}	14.22^{h}	12.07^{lm}	10.87^{a}
T_2	5.86^{n}	10.33^{j}	8.96^{m}	8.38^{c}	6.43^{qr}	13.29^{k}	11.20^{o}	10.31^{c}
T_3	5.88^{n}	10.89^{i}	9.53^{l}	8.76^{b}	6.65^{qr}	13.49^{jk}	11.66^{n}	10.60^{b}
T_4	6.03^{n}	11.19^{gh}	10.00^{k}	9.07^{a}	6.73^{q}	13.90^{hi}	11.86^{mn}	10.85^{a}
T_5	5.93^{n}	11.02^{hi}	9.82^{k}	8.92^{b}	6.64^{qr}	13.64^{ij}	11.91^{mm}	10.74^{ab}
		±0.034					±0.048	
Mean	5.94^{r}	10.78^{d}	9.52^{c}		6.52^{g}	13.49^{c}	11.56^{f}	
Soil depth (cm)								
	±0.068		±0.039			±0.095	±0.055	
0-15	3.20^{a}	7.35^{o}	4.45^{r}	5.00^{d}	3.92^{p}	11.06^{k}	5.99^{n}	6.99^{d}
15-30	5.20^{q}	9.37^{l}	9.13^{m}	7.90^{c}	5.60^{o}	14.38^{h}	12.30^{j}	10.76^{c}
30-60	6.76^{p}	12.84^{i}	12.10^{k}	10.57^{b}	7.83^{m}	14.40^{h}	13.76^{i}	12.07^{b}
60-90	8.58^{n}	13.56^{h}	12.41^{j}	11.52^{a}	8.73^{l}	13.90^{i}	14.21^{h}	12.28^{a}
		±0.034					±0.048	
Mean	5.94^{g}	10.78^{c}	9.52^{f}		6.52^{g}	13.49^{c}	11.56^{f}	
C.V. (%)	6.63				7.678			

For each growing season, means followed by the same letter(s) are not significantly different at 5% level according to DMRT. P1: Before sowing the crop P2: Mid-season P3: After crop harvest.

TABLE IV. PERCENT RETAINED RUNOFF AND SOIL LOSS DURING DIFFERENT STORMS AND CROP GROWTH STAGES

Crop growth stage	Treatment	Season 1			Season 2		
		Rainfall intensity (m/h)	Retained runoff		Rainfall intensity (m/h)	Retained runoff	
			mm	%		mm	%
Initial stage	T_0	31.5	13.1	41.30	16.4	4.6	35.22
	T_1		18.4	57.65		7.1	45.72
	T_2		13.8	43.42		4.8	36.69
	T_3		15.1	47.28		5.5	42.55
	T_4		16.8	52.57		6.4	49.59
	T_5		16.1	50.70		6.3	48.20
Development stage	T_0	17.1	8.9	61.66	29.5	13.3	22.73
	T_1		11.3	78.47		17.9	30.58
	T_2		9.4	65.27		14.9	24.85
	T_3		9.7	67.64		15.4	26.14
	T_4		10.4	72.22		16.6	28.33
	T_5		10.1	70.42		15.8	26.90
Mid-season stage	T_0	29.6	10.1	59.84	22.4	8.6	38.12
	T_1		12.6	75.22		11.0	48.37
	T_2		11.0	65.14		9.4	41.67
	T_3		11.2	66.35		10.0	43.92
	T_4		11.8	70.45		10.4	45.93
	T_5		11.6	69.03		10.2	45.13
Late season stage	T_0	20.6	14.0	63.25	17.8	8.6	38.12
	T_1		16.2	73.35		11.0	48.37
	T_2		14.7	66.58		9.4	41.67
	T_3		15.3	69.35		10.0	43.92
	T_4		15.7	70.78		10.4	45.93
	T_5		15.6	70.47		10.2	45.13

TABLE V. AVERAGE VALUES OF SOIL MOISTURE CONTENT (V/V) AS INFLUENCED BY SOIL DEPTH AND WATER HARVESTING TECHNIQUE

Water harvesting technique	Soil depth (cm)									
	Season 1					Season 2				
	0-15	15-30	30-60	60-90	Mean	0-15	15-30	30-60	60-90	Mean
		±0.097		±0.048			±0.135		±0.067	
Control	4.36	7.56	9.82	11.23	8.24^{c}	6.65	9.76	10.88	11.94	9.79^{d}
Mulching	5.39	8.21	11.02	11.75	9.09^{a}	6.96	11.28	12.75	12.50	10.87^{a}
Intercropping	4.47	7.53	10.23	11.31	8.38^{c}	6.68	10.45	11.91	12.18	10.31^{c}
Stone bunding	5.07	7.95	10.58	11.46	8.76^{b}	7.09	10.88	12.13	12.30	10.60^{b}
Semi-circular earth bund	5.41	8.22	10.93	11.72	9.07^{a}	7.34	11.19	12.42	12.42	10.85^{a}
L-shaped earth bunding	5.29	7.95	10.83	11.63	8.92^{b}	7.20	11.09	12.34	12.32	10.74^{ab}
	±0.039					±0.055				
Mean	5.00^{g}	7.90^{f}	10.57^{e}	11.52^{d}		6.99^{h}	10.76^{g}	12.07^{f}	12.28^{e}	
C.V. (%)	6.63					7.68				

For each growing season, means followed by the same letter(s) are not significantly different at 5% level according to DMRT. When no letters are shown, the interaction means were not significant.

TABLE VI. MEANS OF GROWTH, YIELD AND YIELD COMPONENT VARIABLES OF SORGHUM PLANT OVER THE WHOLE EXPERIMENTAL PERIOD AS AFFECTED BY WATER HARVESTING TECHNIQUES

Water harvesting technique (T)	Final seedling emergence (%)	Plant density	Number of		Fresh matter weight (T/h)	Dry matter weight (T/ha)	Plant height at harvest (cm)	Head length (cm)	Plants producing heads (%)	Head weight (g)	1000 - grain weight (g)	Total grain yield (T/ha)
			Total tillers per plant	Effective tiller per plant								
Season 1												
T_0	80.86^{b}	12.21^{b}	1.87^{b}	0.47^{c}	3.60^{b}	0.904^{c}	133.41^{c}	14.21^{bc}	25.14^{b}	85.78^{b}	27.22^{c}	0.21^{b}
T_1	84.69^{a}	13.17^{a}	2.15^{a}	0.74^{a}	4.45^{a}	1.539^{a}	198.96^{a}	15.68^{a}	34.42^{a}	95.54^{a}	32.57^{a}	0.38^{a}
T_2	81.11^{b}	12.42^{b}	1.91^{b}	0.48^{c}	3.60^{b}	0.907^{c}	136.62^{c}	14.03^{c}	24.96^{b}	85.61^{b}	27.59^{c}	0.21^{b}
T_3	83.64^{a}	13.05^{a}	2.06^{a}	0.68^{b}	4.38^{a}	1.474^{b}	165.95^{b}	15.13^{ab}	33.26^{a}	93.07^{a}	30.22^{b}	0.37^{a}
T_4	83.75^{a}	13.11^{a}	1.12^{a}	0.72^{ab}	4.44^{a}	1.531^{a}	193.35^{a}	15.51^{a}	33.83^{a}	94.64^{a}	31.16^{b}	0.38^{a}
T_5	83.67^{a}	13.00^{a}	2.08^{a}	0.71^{ab}	4.40^{a}	1.489^{ab}	164.73^{b}	15.25^{a}	33.72^{a}	94.17^{a}	30.46^{b}	0.38^{a}
S.E ±	(0.393)	(0.140)	(0.044)	(0.016)	(0.059)	(0.018)	(2.962)	(0.305)	(1.166)	(0.736)	(0.392)	(0.005)
C.V. (%)	1.64	3.79	7.51	8.48	4.93	4.72	6.20	7.06	13.07	2.79	4.54	4.83
Season 2												
T_0	83.55^{c}	14.82^{a}	2.30^{b}	2.27^{a}	9.68^{b}	4.019^{a}	111.84^{d}	13.78^{a}	82.09^{a}	51.38^{a}	23.52^{a}	1.72^{c}
T_1	92.78^{a}	15.72^{a}	2.89^{a}	2.39^{a}	10.71^{a}	4.243^{a}	133.04^{a}	14.14^{a}	82.88^{a}	53.43^{a}	23.75^{a}	1.83^{a}
T_2	84.95^{c}	15.13^{a}	2.32^{b}	2.30^{a}	10.08^{ab}	4.134^{a}	126.00^{c}	13.93^{a}	82.28^{a}	52.38^{a}	23.66^{a}	1.73^{bc}
T_3	88.00^{b}	15.43^{a}	2.79^{a}	2.31^{a}	10.37^{ab}	4.184^{a}	126.49^{c}	13.84^{a}	82.39^{a}	51.98^{a}	23.65^{a}	1.76^{abc}
T_4	88.08^{b}	15.50^{a}	2.82^{a}	2.36^{a}	10.59^{a}	4.189^{a}	130.86^{ab}	14.00^{a}	82.84^{a}	52.82^{a}	23.70^{a}	1.81^{ab}
T_5	87.78^{b}	15.43^{a}	2.82^{a}	2.33^{a}	10.56^{a}	4.214^{a}	128.54^{bc}	13.95^{a}	82.74^{a}	52.46^{a}	23.61^{a}	1.79^{abc}
S.E ±	(0.885)	(0.256)	(0.058)	(0.035)	(0.220)	(0.137)	(1.394)	(0.280)	(0.502)	(0.767)	(0.334)	(0.025)
C.V. (%)	3.50	5.78	7.54	5.14	7.38	11.40	3.83	6.96	2.11	5.07	4.89	4.86

For each growing season, means within the same column followed by the same letter (s) are not significantly different at 5% level according to Duncan's Multiple Range Test.

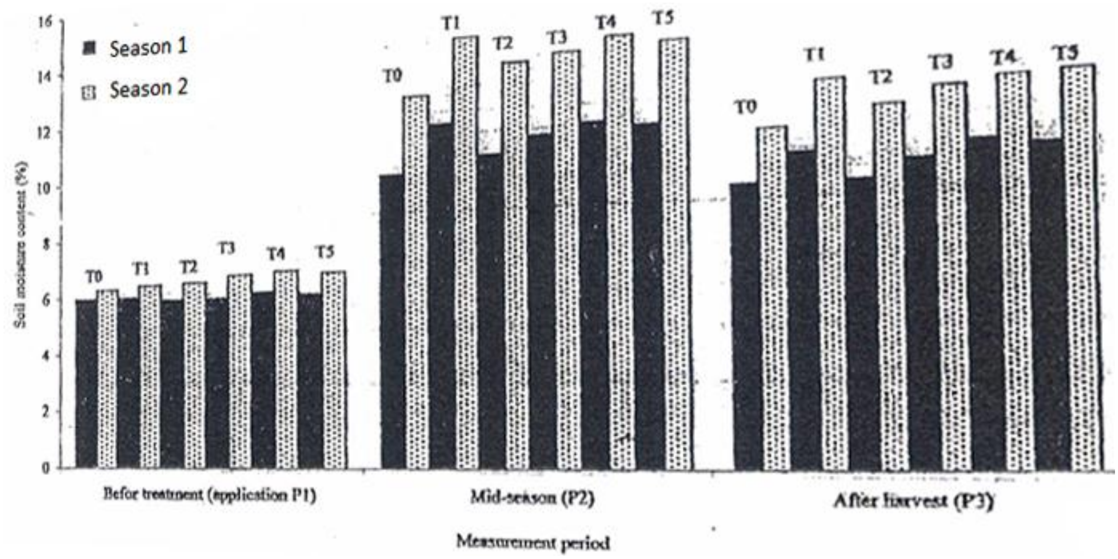


Figure 1. Soil moisture content (v/v) as influenced by measurement period

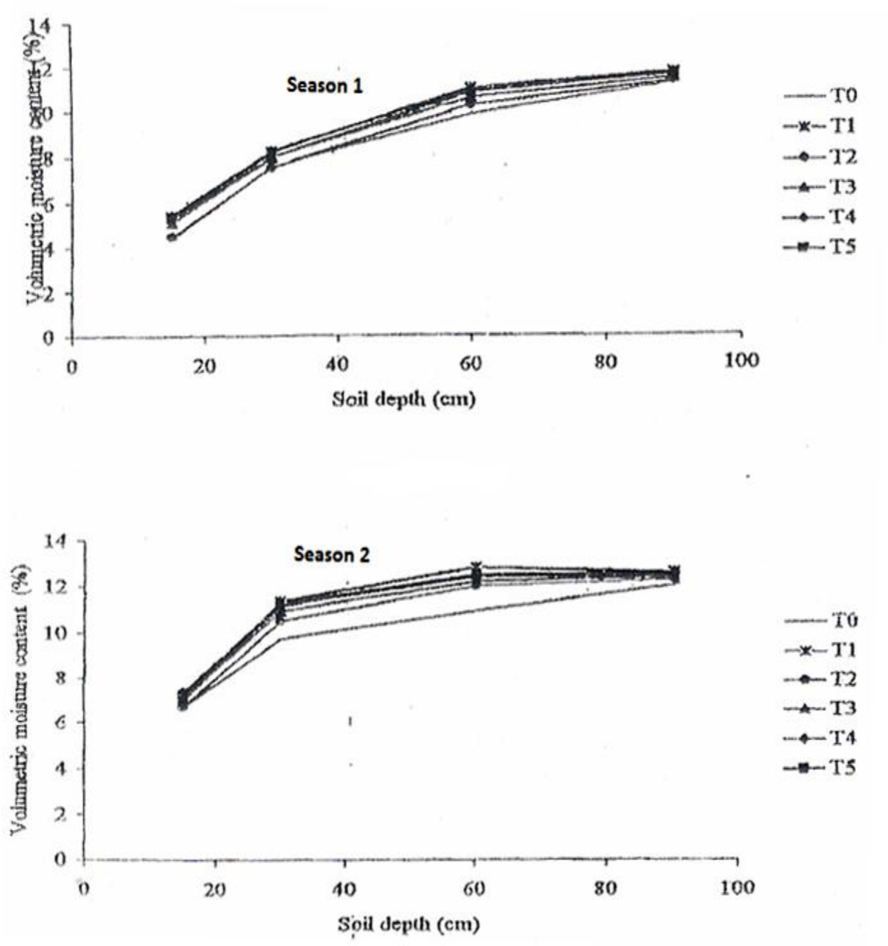
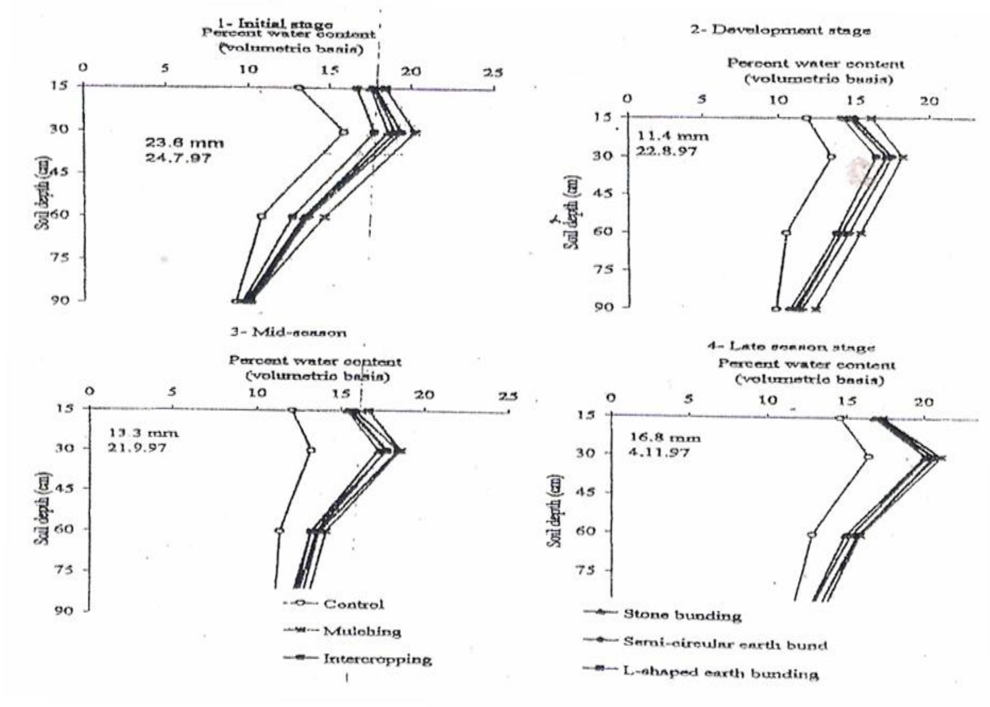
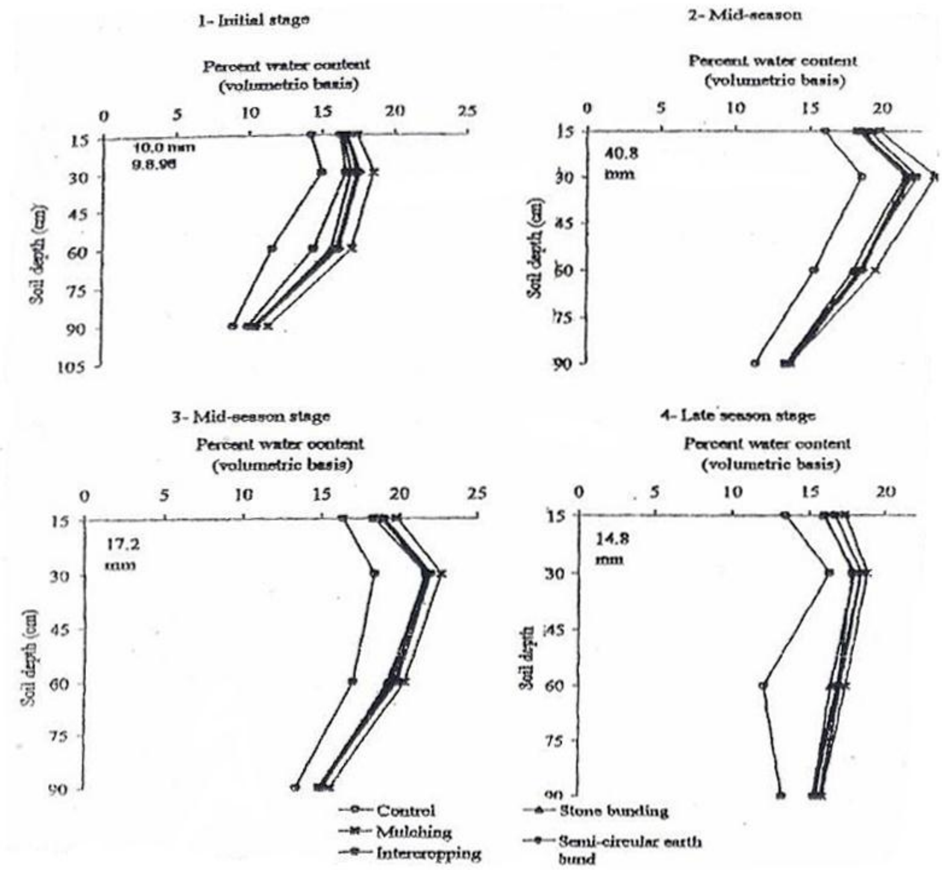


Figure 2. Soil moisture content (v/v) as influenced by soil depth



(a)



(b)

Figure 3. a) Volumetric moisture content at four stages of plant growth as affected by water harvesting techniques in season 1. b) Volumetric moisture content at four stages of plant growth as affected by water harvesting techniques in season 2

IV. Discussion

Water harvesting techniques under study showed highly significant differences in both growing seasons. They improved water storage capacity of the soil through reduction of runoff and surface sealing and permitting more time for ponded water to infiltrate. T_1 treatment was founded to be superior in runoff retention and moisture storage at all soil depths, immediately after rainfall and during wet periods. This was attributed mainly to the porous character, which improved structure and permeability under mulch, as a result of soil fauna activity and probably partial decomposition of straw mulch. Additional factors contributing to the superiority of mulching over the other techniques were suppression of evaporation rate within limited periods of time after rainfall and protection of the soil surface from the beating action of raindrops. [2] Suggested that for adequate soil protection, water retention and proper plant growth the straw mulch should be applied to cover 70-75% of the soil surface. While [3] found 36% reduction in runoff with mulch applied in bands and provided only 20% surface cover. Other researchers [4]- [7] have stated similar effects of mulches on protecting the surface and improving the structure and moisture status of the soil. Despite, the good performance of mulching technique, the porous soil under the mulch can enhance evaporation losses from surface layers during the prolonged dry periods. Similar suggestions were reported by [5], [8].

On the other hand, the bunded plots (T_4 and T_5) only slowed down and accumulated the runoff water and eroded soil particles immediately above the bunds, thus retained more water at the lowest point and against the bund arms. Earth bunding was superior over mulching in moisture storage at 0-30 cm depth during dry periods. Furthermore, the superiority of T_4 over T_5 was attributed to its greater impounded area (6.3 m^2 as compared to 3.5 m^2 for T_5). This was reflected on better but non-significant plant performance. The lower moisture content under T_0 could be attributed to the severe competitive effect of the crop roots on the available soil water. Furthermore, interception by canopy cover could prevent light rains from wetting the soil or contributing to plant growth . These inferences are in conformity with what has been stated by [9] in that interception by dense vegetative covers commonly amounts to 25% of the annual precipitation.

The influence of the water harvesting techniques on soil structure and water conservation was reflected by the significant variations in growth and yield attributes of the tested plants. On the other hand, the non-significant effect of the techniques on some of the plant variables in the second growing season might often be due to the frequent rainfall and ample soil moisture in all techniques. The main reasons for superiority of mulching and earth bunding on all plant variables could be the adequate initial plant, available soil water, less soil surface level change, improved soil structure and fertility, and better aeration. [10] Found that sorghum with high and medium water levels grew taller, yielded more and unused water more efficiently than sorghum, with low water level at different growth stages.

Similar results were also reported on sorghum in USA [11] and on maize in the Sudan [12]. While in the first growing season, both groundnut and sorghum had suffered from the severe moisture stress conditions during flowering, heading or pegging, which contributed greatly to vegetative growth and yield decreases. These results were supported by the results of [13], [14]. Furthermore, the partial shading of groundnut plants by the tall-growing sorghum cultivar during flowering and dry matter accumulation phases could affect peg formation and pod yield through reducing photosynthesis and/or promoting aerial shoot elongation. This indicated that relative advantage of intercropping were less under conditions of severe moisture stress. These results and inferences corroborate the findings of other researchers [15], [16] in various parts of the world, despite the low yields of intercropping and stone barrier treatments, relative to the other techniques, the net returns were found to be higher due to higher combined yield of the former and the low cost of production of both techniques. These findings are in consistent with the results of [17].

V. Conclusions

In conclusion, the mulching material and crop canopy reduced the formation of surface crusts and hence improved the water infiltration into the soil, although its use is not promising under dry land farming conditions. The short growing early-maturing sorghum is more suitable for intercropping especially under short rainy seasons than the tall late- maturing sorghum. However, intercropping is beneficial under adverse situations of climate expect at times of extreme water shortages. Because they are economically and technically feasible particularly in small holdings, intercropping and stone barrier are proposed as the best combination for soil and water conservation and crop production.

References

[1] A. Clift- Hill, “ Darfur historical rainfall records. Jebel Marra Rural Development project, Agriculture services Department,” Adaptive Research Division ,Zalingei Sudan, 1987.

[2] H.A. Elwell, M.A. Stocking, “Vegetal cover to estimate soil sustainability implications,” FAO soil Bulletia No 71, FAO,Rome, 1976.

[3] H.S. Sur, P.S. Mastana, M.S. Hadda, Effects of rates and modes of mulch application on runoff sediment and nitrogen loss on cropped fields. Tropical Agriculture, 69, 319-321, 1992.

[4] L.E.A. Daislley, S.K. Chong, F.J. Olsen, L. Singh, C. George, “Effects of surface – applied grass mulch on soil water content and yields of cowpea and eggplant in Antigua,” Tropical Agriculture, 65, 300-304, 1988.

[5] R.I. Papendick, J.F. parr, “The values of crop residues for water conservation Pp. 183-190. In :soil, Crop and Water Management in the Sudano- Sahelian Zone,” proceeding of an International Workshop, 11-16 Jan.1987, 1989.

[6] FAO, “Sustainable dry land cropping in relation to soil productivity,” FAO Soils Bulletin No.72. FAO, Rome, 1995_a.

[7] FAO, “Tillage system in the tropics : management options and sustainability implications,” FAO Soils Bulletin. FAO, Rome, 1995b.

[8] R.H. Phipps, J. Cochrance, “A note on the effect of bitumen mulch on soil temperature and forage maize production,” A agriculture Meteorology, 7, 797-399, 1977.

[9] G.O. Schwab, R.K. Ftevert, T.W. Edminster, K.K. Barnes, “Soil and Water Conservation Engimeering. 3rd ed .,” Jon Wiley and sons Inc. New York, 1981.

[10] P.W. Unger, O.R. Jones, "Effect of soil water content and growing season straw mulch on grain sorghum," Soil Science Society of American Journal 45, 129-134, 1981.

[11] J.W. Doran, W.W. Wilhelm, J.F. Power, "Crop residue removal and soil productivity with no- till corn, sorghum and soybean," Soil Science Society of American Journal 48, 640- 645, 1984.

[12] A.E. Mahmoud, "Response of Late Planted Potato(Solanum tubeosum L.) to Mulching and intercropping under Sudan condition," M.Sc. Thesis University of Khartoum, Sudan, 1994.

[13] K. Ahuja, S.P. Singh, "Irrigation requirement of sorghum based intercropping systems in spring season in North – West India," Journal of Agronomy 35, 400-407, 1990.

[14] V. Ravindra, P.C. Nautiyal, Y.C. Joshi, "Physiological analysis of drought resistance and yield in groundnut (Arachis hypogaea L.), " Tropical Agriculture, Trinidad and Tobago, 67(4), pp.290-296, 1990.

[15] M.R. Rao, R.W. Willey, "Preliminary studies of intercropping combinations based on pigeon pea or sorghum," Experimental Agriculture, 16, 29-39, 1980.

[16] V.R.N. Chinene, D. Mbewe, D. Lungu, "Measuring soil loss in different land-use systems on an Oxic Paleustalf in Lusitu, Zambia," Tropical Agriculture, 67(3), pp.221-222, 1990.

[17] J.E.G. Ikeorgu, S.O. Odurukwe, "Increasing the productivity of cassava/maize intercrops withgroundnuts (Arachis hypogaea L.)," Tropical Agriculture, Trinidad and Tobago, 67(2), pp.164-168, 1990.

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