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Effect of Different Rainwater Harvesting Techniques (RWHT) On Yield of Pearl Millet Intercropped with Cow pea, North Darfur-Sudan

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Abstract: In North Darfur state, Sudan, field experiment were conducted for two rainy seasons 2011/12 and 2012/13 to study the effect of different rainwater harvesting methods on yield of pearl millet intercropped with cowpea. The water harvesting techniques studies were as follow: W1 (Terracing system), W2 (V- shape micro- catchments), W3 (Contour bunds), W4 (Trapezoidal bunds method), W5 (rain fall control). Millet intercropped with cow pea and grown sole. The experiment was arranged in split- plot design replicated fourth times. The results showed significant difference among harvesting methods techniques for 50% flowering and maturing, millet panicle length, 100 seeds weight, total seed yield and straw yield. The treatments of normal watering by rain-fall gave the lowest values. Also intercropping of millet with cowpea revealed significant difference. In general application of rain water harvesting techniques (W1, W2, W3 and W4) increased yield and yield components of millet compared with control.
Keywords: pearl millet, rainwater harvesting techniques (RWHT), intercropped, cow pea

INTRODUCTION

Agriculture remains the largest employment sector in the most developing countries. Agriculture in dry land area must be improved to meet the requirements of growing world population. A major contribution to this improvement will be the capture and use of greater portion of limited and highly variable precipitation in dry land areas [1].

Pearl millet (*Pennisetum glaucum* L.) is the main staple food in Darfour region – Sudan. Today it is getting more attention due to increasing evidence of less seasonal rainfall, terminal heat, frequent occurrence of extreme water resources. Annual rainfall and its monthly distribution are face highly variable in this zone. Owing to the rainfall flocculation, soil water deficits that frequently occurs during crop growth lead to non-uniform distribution of rain which reduce yield in traditional system [2].

Rainwater harvesting, as a potential source of water for Agriculture, has been the focus of much attention in recent years, although there is a long history of rain water harvesting in Sudan.

Farmers in Darfur have worked to overcome the problem of irrigation, whilst avoiding the high costs of many modern irrigation techniques, through the rehabilitation and expansion of traditional water harvesting techniques in the area. In the Sudan, research on water harvest was practice under tradition rain fed e.g. Mohamed [3] who reported that in the western Sudan inhabitants devised several indigenous techniques for rain water harvesting (collecting) system. Like hafirs, rahads, fulas and terraces.

Omer and Elamin [4] in Kordafan reported that the ploughting and contour bounding of gardud soil improve physical properties, soil moisture storage and sorghum yield. Many witness and researches believe that the key solution for Sudan situation is rain water harvest [5]. (ITDG) Intermediate Technology Development Group [6] work in food security water harvesting project in Northern Darfur State explained that the C-shaped Micro catchment plough and training helped farmer to cultivate Wadi soil and increase crop production.

Since the North Darfur is situated in the dry land, annual rainfall range between 200-300 mm rainfall, the interest in water harvesting is one of the most important work to ensure food crops and surplus for export [7]. Reuse of agricultural resources in the use of agricultural land to achieve the greatest return of rainfall and climate has made it clear that the prevailing practices in many parts of Sudan. Rain water harvesting has a potential of addressing spatial and temporal water scarcity for domestic consumption, agricultural development and overall water resources management.

Intercropping is a common cropping system practice by almost all small scale farmers. Many researchers have reported the advantages of intercropping over monocropping [8] and [9]. Intercropping resulted in more efficient utilization of moisture by the intercrops compared to the sole crops [9]. The main objective of this paper was to study the effect of different rainwater harvesting (RWH) on yield of pearl millet intercropped with cow pea, North Darfour-Sudan.

Materials and Methods

Field experiments were conducted at Umhojora Village, 3 Km of Kabkabiya Town, North Darfur state, Sudan (Latitude 13. 64 N and Longitude 24.08 E, with altitude of 850m above the sea level). During 2011/12- 2012/13 growing season, under rain fed condition, to study the effect of five water harvesting techniques on growth and yield of pearl millet intercropped with cow pea.

The area lies on semi- arid- savannah zone, which is affected by the elevation of Jabel Marra Massif (rain and temperature) for the larger part of area under consideration The rainy season usually begins in first July and extends to first October, with occasional limited shower in May and November, the average rain during Last ten year varied from 279mm to 561mm [10].

The seed of pearl millet and cowpea was obtained from Ministry of Agriculture North Darfur State namely Darmassa and Eyn Elghazal. Three Methods of intercropping treatment were chosen (Millet and cowpea as follow: Ms (Millet sole), Ls (cowpea sole) and ML (Millet+cowpea). A number of water harvest techniques were selected and applied based on local farmers technical Knowhow and the availability of local construction materials. The water harvesting techniques studies were as follow: W1 = Terracing system, W2 = V- shape micro- catchments, W3 = Contour bunds, W4 = Trapezoidal bunds method, W5 = rain fall control.

The main treatments were represented by three plots 10x50 m each plot had three terracing 10 m long x 30 cm with, three V- shape micro –catchment, three contour bunds, five trapezoid bunds method and one rain fall as control 10X10 m Figue (1). Hand tools such as hoe and shovels were used to construct small earth bunds parallel, terracing were raise 30 cm, with base of 30cm, water would accumulate.

The treatment Were: MsW1 = Millet sole millet + terrace system, MsW2 = Millet sole + V- shape micro catchment, MsW3 = Millet sole + Contour bunds, MsW4 = Millet sole t + Trapezoid bunds, MsW5 = Millet sole t + rain fall control, LsW1 = Sole cowpea+ Terrace system, LsW2 = Sole cowpea + V- Shape-micro catchment, LsW3 = Sole cowpea + Contour Bunds, LsW4 = Sole Cowpea + Trapezoid, LsW5 = Sole Cowpea + rainfall control, MLW1 = Intercropping (Millet- Cowpea) + Terrace, MLW2 = Intercropping (Millet- cowpea) + V-shape micro catchment, M LW3= Intercropping (Millet-cowpea) + Contour, M LW4 = Intercropping (Millet- cowpea) + Trapezoid MLW5 = Intercropping (Millet-cowpea) + rainfall control.

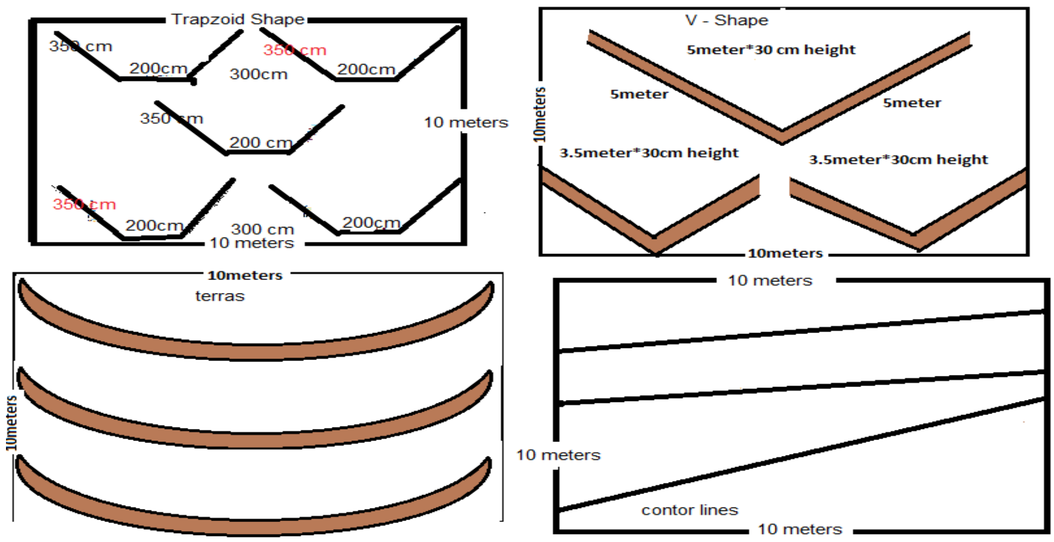

Fig-1: Water harvesting Technique (Trapezoid- V-Shape- Local terrace and Contour bundle)

The Experiment was arranged in split- plot design, with four replication to make a total of 60 plots (3x5x4) the plot area is 10x10m. The main plots were allotted for the intercropping and sub plots for the water harvesting Techniques.

Sowing was done manually, and was carried on 5 June 2011, in first season, and on 9 June 2012, in second season. for both experiment the seed rate is 5 Kg for millet and 20 Kg for cowpea, all plot had an equal seed rate to standardize the plant population for experiment plots, cowpea seed were plant on hole alternated with millet seeds, raw intercropping (1:1) seed were sow manually in holes 25 cm apart, the 5 seed per hole for millet and 4 seed for cowpea re-sowing was done, germination was started after 5 day, , cowpea was thinned to 3 plant per hole, while millet was thinned to 2-4 plant per hole hand weeding was practice three time for each season, the insecticide Marcalla was used to control the insect and grasshopper after two month which appeared during the flowering stage of cowpea, harvesting was done after 100 days from sowing.

Parameters taken include; day to 50% flowering, day to maturity, panicle length, 100 seed weight, yield in gm/ha and straw yield.

RESULTS AND DISCUSSION

Day to 50% flowering of Millet

The effect of the water harvesting techniques and intercropping on day to 50% flowering of millet presented in Table (1). There were no significant different in day to 50% flowering on intercropping and sole millet between all treatment. However intercropped (ML) treatment tended to flower earlier than other in first and second season, whereas millet sown sole (Ms) tended to flower late than other treatment in both season.

The analysis of variance revealed significant effect of water harvest on day to 50% flowering of millet in both growing season. There were no significant differences between W1, W2, W3 and W4 (55.88, 55.63, 55.63 and 56.72). On the other hand, W5 showed lowest day to 50% flowering in second season, while it showed highest day to 50% flowering (57, 63) in first season.

The effect of the water harvesting techniques and intercropping on day to 50% maturity of millet presented in Table (2). There were no significant differences in day to maturity on intercropping and sole millet, between all treatments. However monocropped millet tended to mature earlier than other intercropping cowpea and millet in first and second season, whereas intercropping tended to mature late than other treatment in both season, there were no significant difference in all water harvest technique on day to maturity in first and second season, exception W5 had significant effect compared to other treatment (W1, W2, W3 and W4) in both season.. Generally interaction between water harvest technique and intercropping was no significant in both growing season 2011/2012 and 2012/2013.

The effects of water harvesting technique and intercropping on millet panicle length in two seasons are presented in Table (3), no significant differences were found between intercropping during first season, but there were significant effect during second season. However, the effect of water harvest techniques was significant during first and second season, W5 produced the shortest panicle length 18.74 cm and 19.36 cm in first and second season respectively. No significant differences were detected between W1, W2, W3 and W4 in first and second season, in addition W1 produced longer panicle length (22.58 cm and 22.40cm) in first and second season respectively, follow by W2 (22,28cm) in first season and W4 (22.21cm) and W3 (21.81cm)in second season.

Table 1: The effect of the water harvesting technique and intercropping on 50% day flowering of millet for two season 2011/2012 and 2012/ 2013

plant stages	Day to 50% flowering season; 2011/2012			Day to 50% flowering season; 2012/2013		
Treatment	**Millet**	**M+C**	**Means**	**Millet**	**M+C**	**means**
W1	54.00^{bcd}	52.50^{cde}	53.25^{c}	56.75^{a}	55^{abc}	55.88^{a}
W2	52.00^{de}	52.00^{de}	52.00^{c}	56.5^{ab}	54.75^{abc}	55.63^{a}
W3	56.00^{b}	55.00^{bc}	55.50^{b}	56.5^{ab}	55.25^{abc}	55.63^{a}
W4	51.00^{e}	53.75^{bcde}	52.38^{c}	58^{a}	55.5^{abc}	56.75^{a}
W5	59.00^{a}	56.25^{ab}	57.63^{a}	52^{c}	53.25^{bc}	52.88^{b}
Means	54.40^{a}	53.90^{a}	54.15	55.95^{a}	54.75^{a}	55.35
CV%			3.51			4.31
SE 1			0.426			0.5339
SE 2			0.673			0.8441
SE 1x2			0.952			1.1937

Means with the same letters are not significantly different at LSD 5%, 1; crop, M = millet, C= cowpea, 2; Water harvesting techniques, W1 = Terracing system, W2 = V- shape micro- catchments, W3 = Contour bunds, W4 = Trapezoidal bunds method, W5 = rain fall control.

Table 2: The effect of the water harvesting technique and intercropping on days of maturity for two season 2011/2012 and 2012/ 2013

plant stages	%50Day of maturity; 2011/2012			%50Day of maturity season 2012/2013		
treatment	Millet	M+C	means	Millet	M+L	means
W1	88.75[a]	89.25[a]	89.00[a]	88.75[a]	89.25[a]	89[a]
W2	89.50[a]	89.50[a]	89.50[a]	89.5[a]	89.5[a]	89.5[a]
W3	87.50[a]	90.25[a]	88.88[a]	87.5[a]	90.25[a]	88.875[a]
W4	90.50[a]	91.00[a]	90.75[a]	90.5[a]	91[a]	90.75[a]
W5	79.00[b]	78.25[b]	78.63[b]	79[b]	78.25[b]	78.625[b]
Means	87.05[a]	87.65[a]	87.35	87.05[a]	87.65[a]	87.35
CV%			2.91			2.91
SE C			0.568			0.5678
SE W			0.898			0.8978
SECxW			1.2697			1.2697

Means with the same letters are not significantly different at LSD 5%, 1; crop, M = millet, C= cowpea, 2; Water harvesting techniques, W1 = Terracing system, W2 = V- shape micro- catchments, W3 = Contour bunds, W4 = Trapezoidal bunds method, W5 = rain fall control.

Table 3: the effect of the water harvesting technique and intercropping on panicle length two season 2011/2012 and 2012/ 2013

plant stages	panicle length season 2011/2012			panicle length season 2012/2013		
treatment	Millet	M+C	means	Millet	M+C	means
W1	22.15[ab]	23.00[a]	22.58[a]	21.10[bc]	23.70[a]	22.40[a]
W2	22.75[ab]	21.80[ab]	22.28[a]	21.00[bcd]	22.15[ab]	21.58[a]
W3	22.70[ab]	20.75[ab]	21.73[a]	21.48[bc]	22.15[ab]	21.81[a]
W4	21.10[ab]	21.08[ab]	21.09[a]	22.28[ab]	22.15[ab]	22.21[a]
W5	19.80[bc]	17.68[c]	18.74[b]	18.90[d]	19.83[cd]	19.36[b]
Means	21.70[a]	20.86[a]	21.28	20.95[b]	22.00[a]	21.47
CV%			9.59			6.91
SE C			0.456			0.3316
SE W			0.721			0.5243
SE C x W			1.0199			0.7415

Means with the same letters are not significantly different at LSD 5%, 1; crop, M = millet, C= cowpea, 2; Water harvesting techniques, W1 = Terracing system, W2 = V- shape micro- catchments, W3 = Contour bunds, W4 = Trapezoidal bunds method, W5 = rain fall control.

Table (4) showed the influence of water harvesting technique and intercropping on 1000-seeds weight during both growing season 2011/2012 and 2012/2013. The weight of the 1000 grains millet was not affected by intercropping treatment on both growing seasons, while it was significant affected by water harvesting technique in first and second season. The average 1000 seed weight was more in the second season 2012/2013 (with an overall mean of 9.31g) than in first season 2011/2012 (with an overall mean of 9.08 g).

In the both growing season, the 1000-seed weight was higher with W4 (10.25g and 10.86g than with other treatment. On other hand, W5 resulted in the lowest 1000-seed weight (6.35g and 6.75gm) with significant difference from other treatment in first and second growing season, W1 also showed no significant different form W2,W3 and W4 in first season, Whereas there were significant difference in second season. These differences are in accordance with the difference in soil moisture content, dry matter weight.

Analysis of variance Table (5), showed significant effect in first and second season, of water harvesting technique on total seed yield of millet. All water harvesting techniques showed greater grain yield in the second season than in the first season. The overall grain mean yield were 0.652 and 0.709 T/ha for 2011/20012 and 2012/2013 growing seasons, respectively. W3 and W4 produced highest total seed yield than W1 and W2 but not significant difference in both growing season. W5 on other hand, produced the lowest seed yield and significant differences from W1, W2, W3 and W4 in first and second season.

General the analysis of variance in Table (5), showed there was significant difference of intercropping on total seed yield for both growing season, intercropping millet (ML) increase the seed yield compared to momocroped (sole millet) in first and second season.

Table 4: The effect of the water harvesting technique and intercropping on 1000 seed weight for two season 2011/2012 and 2012/ 2013

plant stages	1000 seed weight season; 2011/2012			1000 seed weight season; 2012/2013		
treatment	**Millet**	**M+C**	**means**	**Millet**	**M+C**	**means**
W1	9.35[a]	9.48[a]	9.41[a]	9.90[abc]	9.85[abc]	9.88[ab]
W2	9.40[a]	9.80[a]	9.60[a]	9.95[abc]	10.10[abc]	10.03[ab]
W3	9.75[a]	9.83[a]	9.79[a]	10.38[a]	7.73[cd]	9..050[b]
W4	9.70[a]	10.80[a]	10.25[a]	10.30[ab]	11.43[a]	10.86[a]
W5	5.45[c]	7.25[b]	6.35[b]	5.58[d]	7.93[bcd]	6.75[c]
Means	8.73[a]	9.43[a]	9.08	9.22[a]	9.41[a]	9.31
CV%			12.73			17.89
SE C			0.2584			0.3726
SE W			0.4086			0.589
SE C x W			0.5779			0.8332

Means with the same letters are not significantly different at LSD 5%, 1; crop, M = millet, C= cowpea, 2; Water harvesting techniques, W1 = Terracing system, W2 = V- shape micro- catchments, W3 = Contour bunds, W4 = Trapezoidal bunds method, W5 = rain fall control.

Table 5: The effect of the water harvesting technique and intercropping on total seed yield for two season 2011/2012 and 2012/ 2013

plant stages	Total seed yield season; 2011/2012			Total seed yield season; 2012/2013		
treatment	**Millet**	**M+C**	**Means**	**Millet**	**M+C**	**means**
W1	9.00[a]	5.10[bc]	7.05[a]	9.60[ab]	5.73[cd]	7.66[a]
W2	9.63[a]	5.23[bc]	7.43[a]	10.18[a]	5.75[cd]	7.96[a]
W3	9.48[a]	5.65[bc]	7.56[a]	10.30[a]	6.18[c]	8.24[a]
W4	9.65[a]	6.28[b]	7.96[a]	10.25[a]	7.15[bc]	8.70[a]
W5	3.53[cd]	1.68[d]	2.60[b]	3.53[de]	2.28[e]	2.90[b]
Means	8.26[a]	4.79[b]	6.52	8.77[a]	5.42[b]	7.0925
CV%			27.42			24.23
SE C			0.3997			0.38
SE W			0.632			0.6076
SE C x W			0.8939			0.8593

Means with the same letters are not significantly different at LSD 5%, 1; crop, M = millet, C= cowpea, 2; Water harvesting techniques, W1 = Terracing system, W2 = V- shape micro- catchments, W3 = Contour bunds, W4 = Trapezoidal bunds method, W5 = rain fall control.

The straw dry matter weight, at harvest, of the millet were influenced by water harvesting technique and intercropping in the 2011/2012 and 2012/2013 growing seasons are illustrated in Table (6), revealed significant effect of water harvesting techniques on straw dry matter yield compared to control W5 in first and second season, Moreover, the effect of water harvesting techniques on straw dry matter yield between W1, W2, W3 and W4 was not significant difference in both season.

Intercropping had significant effect on straw dry matter weight during both growing season. Lower straw dry matter yield were observed in the season 2011/212 than in the 2011/2013 growing season, W3 treatment produced the highest straw dry matter yield values (2377.5 dry Kg/ha) in second growing season, whereas W5 produced lowest values (1170 dry Kg/ha) in first growing season, there were no significant difference in straw dry weight between, V-shape, contour bund, terrace and trapezoid shape in all treatment except control W5 which differed significantly, the average mean of all treatment in second season 2012/2013 (233.3, 234.38, 237.75.234.25 and 147.63 kg/) were greater than first season 2011/2012.

In the same line RWH (Rain Water Harvesting) techniques has been shown to improve the yield of maize and sunflower [11]. Also [12] reported that supplementary irrigation increased crop yield by 20% [13] concluded that rain water harvesting techniques have shown significant impact on improved soil moisture runoff and ground water recharge, and increased agricultural production, which in turn reduces risks and deliver positive impacts on other ecosystem. Besides increased yields, [14] reported that RWH methods also aimed at stabilizing variation in crop yields and insuring food security.

Significant effects of cropping system and cultivars were observed for cowpea grain yield, the relationship between the yield of cowpea cultivars and millet when intercropped was negative [15].

Table 6: The effect of the water harvesting technique and intercropping on Straw yield at seedling, flowering and maturity stage Second season 2011/2012 and 2012/ 2013

plant stages	Straw yield; 2011/2012			Straw yield; 2012/2013		
Treatment	Millet	M+C	Means	Millet	M+C	means
W1	293.50[a]	146.75[b]	220.13[a]	301.25[a]	165.75[c]	233.50[a]
W2	288.75[a]	145.50[b]	217.13[a]	304.00[a]	164.75[c]	234.38[a]
W3	292.25[a]	132.25[bc]	212.25[a]	312.50[a]	163.00[c]	237.75[a]
W4	271.50[a]	157.50[b]	214.50[a]	302.75[a]	165.75[c]	234.25[a]
W5	148.00[b]	86.00[c]	117.00[b]	191.00[b]	104.25[d]	147.63[b]
Means	258.80[a]	133.60[b]	196.2	282.30[a]	152.70[b]	217.5
CV%			6.91			4.78
SE C			7.3993			2.3247
SE W			11.699			3.6757
SE C x W			16.545			5.1982

Means with the same letters are not significantly different at LSD 5%, 1; crop, M = millet, C= cowpea, 2; Water harvesting techniques, W1 = Terracing system, W2 = V- shape micro- catchments, W3 = Contour bunds, W4 = Trapezoidal bunds method, W5 = rain fall control.

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