Journal of Environmental Science and Engineering, 5 (2011) 1079-1083

# Supplementary Irrigation and Soil Amendment Management with Sorghum on Khor Abu Habil (Sudan)

M.A. Omer[1] and E.M. Alamin[2]

*1. Water Harvesting Research Institute, Khartoum 13391, Sudan*

*2. Agricultural Economic and Policy Research Center, Khartoum 30, Sudan*

Received: February 10, 2011 / Accepted: April 20, 2011 / Published: August 20, 2011.

**Abstract:** This research was conducted for 3 cropping seasons at Elobeid Research Station in Western Sudan. The objectives were to improve the irrigation water and soil management and crop yield by evaluating the response of sorghum crop to different supplementary irrigation regimes and soil amendments management in flood basin irrigated scheme. The existing flood irrigation practice was basically conducive to late planting, weed growth, late season water stress and pest and diseases attack. Four levels of each irrigation regimes and farm yard manure (FYM) treatments arranged in split-plot design were tested. Rainfall, field capacity, irrigation water added, profile water content, plant height, yield components and water use efficiency were measured. Grain yield was significantly increased ($p < 0.01$) with irrigation treatments where 1919, 1870 and 878 kg/ha were obtained for one, two and no irrigation treatments, respectively. The 3 irrigations treatment has produced relatively lower grain yield (1679 kg/ha). FYM treatment up to 4-8 t/ha showed increase in grain yield. Water added in 1, 2 and 3 irrigation treatments amounts to 4475, 5302 and 6035 $m^3$/ha, respectively which supplmented the rainfall by 23%, 45% and 65%, respectively. Water use efficiency was greater with 1 and 2 irrigation treatments and 4 t/ha FYM which reached 0.43, 0.35 and 0.28 kg/$m^3$, respectively. The result concludes that providing supplementary irrigation from crop establishment to mid season was found sufficient to improve crop productivity.

**Key words:** Supplementary irrigation, sorghum, water stress.

## 1. Introduction

Permanent water supplies for irrigation in western Sudan are limited and region depends entirely on rained agriculture. Khor AbuHabil as ephemeral stream that flows during July-October represents the main source of irrigation water. Khor AbuHabil has an average annual discharge of 176 million $m^3$ and only about 56 million $m^3$ is used for irrigation and domestic purposes. ElSemih Agricultural Scheme (EAS) is the largest irrigated area along Khor AbuHabil flood plains. The current cultivated area is 8,000 feddan (3361 ha) out of 24,000 feddan (10.000 ha) as potential and irrigable area. The scheme utilizes the seasonal flood irrigation water contained on flood basins to produce sorghum, cotton and vegetables. Average sorghum grain and cotton yield at ElSemih Agricultural Scheme are generally low compared to other sorghum and cotton irrigated areas in Sudan. Poor flood irrigation management appeared to contribute to this low yields. Although, flood irrigation water is the most vital input for crop production in EAS, yet large amount of it is lost to evaporation by ponding water in 80-120 cm deep basins for 30-45 days. This constitutes a serious water management and soil degradation problem associated with water logging, leaching of plant nutrients and aeration in agricultural soils that lead to low crop productivity and economic loss.

ELSemih flood irrigation area is predominately clay to clay loam soils with clay contents in the range 50-68%, pH 8, high cation exchange capacity (56 me/100 g) ,very low organic carbon (0.7%) and < 0.05

E.M. Alamin, Ph.D., main research field: agric. economics. E-mail: eltighani@yahoo.com.

**Corresponding author:** M.A. Omer, Ph.D., main research field: water harvesting/irrigation agronomist. E-mail: mekkiomer@hotmail.com.

total nitrogen content. The soils usually have available water holding capacity of about 140-180 mm/m of soil and readily available water capacity in the range of 100-120 mm/m depth of soil.

The current irrigation water management in the scheme faces a number of production constraints, mainly:

- Uneven distribution of irrigation water in the flood basins due to sedimentation;
- Large depth of irrigation water given in flood irrigation (60-80 cm) creates water logging which imposes late planting (August-September);
- Late season moisture stress and pests and diseases usually occur due to late planting;
- Flood irrigation stimulates weeds growth which completely smothers the mother crop when planted late after flood receding and vigorously depleting the soil moisture reserve.

## 2. Objectives

The general objective of this research is to enhance irrigation water and soil management practices in EAS for improving sorghum productivity through supplementary irrigation and organic manure application. Specifically the research aimed at:

- To test the effect of soil amendment and supplementary irrigation treatments on crop yield;
- To evaluate the response of sorghum crop to soil and water management practices;
- To determine the economic net benefit returns from the water and soil management practices.

Supplementary irrigation is defined as the amount of water which added to rain-fed crops to supplement the rainfall deficiency for improving crop productivity. This is mostly because of unreliability of rainfall in many arid and semi-arid areas. Several studies were reported in the literature on supplementary irrigation with positive impact on rain-fed productivity. However, research on supplementary irrigation has in general been lacking or limited in Sudan. Therefore, this research is an attempt to fill the gap in this area of research and to provide information to be utilized as water management alternative technique to flood irrigation in both constraints removing and achieving economic benefits. Lal et al. [1] summarized evidence, which demonstrates that improved technological innovations including early improved variety sowing, farm manuring, mulch farming, soil and irrigation water management are important packages designed to boost food production in Sub-Saharan Africa.

## 3. Material and Methods

The experiment was conducted at EAS during (1993/94-1995/1996) cropping seasons by Elobeid Research Station as apart of the Regional Network for Supplementary Irrigation and Water Management at the Farm Level (RAB/90/005) Project activities. Treatments were four levels of supplementary irrigation regimes and farm yard manures (FYM) each, arranged in split-plot design with former as main plots and latter as sub-plot in 3 replications. The irrigation treatments were irrigating once, twice, three times and control (rainfall only). Timing of irrigation is scheduled at early (crop establishment), mid season (within season dry spell) and late season (flowering stage). The exact amount of irrigation water needed was conveyed via irrigation hose connected to small motorized pump of known discharge installed on supply channel. Levels of FYM are 0, 4, 8 and 12 t/ha. The FYM material was composted for 6 weeks before its use. Experimental plots were 5 m by 7 m. All plots were disc plowed first, leveled and furrow ridged to facilitate irrigation operations. Stone et al. [2] has emphasized the importance of furrow irrigation in conserving water when properly performed with acceptable gradient. Sorghum seeds of improved variety Yarwasha were planted in the periods 15-24 July, depending on the availability of irrigation water in the Khor and effective rainfall at the rate of 4 kg/feddan (9.5 kg/ha) and thinned to 3-5 plants per holes at 80 cm by 50 cm spacing. Other cultural practices of weeding, irrigation and harvesting were performed manually.

Field data collection included initial soil hydraulic properties (water holding capacity, bulk density and porosity), rainfall, irrigation water added, plant growth and yield components and calculation of water use efficiency. Because of access tube limitation, the profile soil water was measured by both neutron probe and gravimetric methods at planting before each irrigation and at harvest to a depth of 100 cm at 20 cm intervals. Measurement of total profile soil water before each irrigation provides estimate of amount of water available and hence the amount of irrigation water needed to fill the soil profile to the field capacity.

## 4. Result and Discussion

### *4.1 Seasonal Consumptive Water Use*

The amount of soil water in the profile before applying irrigation treatments was subtracted from the soil field capacity (17.42 cm) and the resultant value was supplemented by irrigation. The amounts of irrigation water added to the available water for each irrigation regime were summed up with other water inputs (effective rainfall-R) and outputs (evaporation Losses-I) estimated as difference between soil water at planting -$Q_p$ and at harvest -$Q_h$ to compute seasonal water use (WU), assuming that surface runoff is restricted and deep percolation is practically negligible in Vertisol soils:

$$WU = R + I + (Q_p - Q_h) \qquad (1)$$

Table 1 presents a typical example of seasonal water use calculation for one irrigation treatment. Other irrigation treatments water uses were similarly calculated. From the three years mean annual rainfall of 401.5 mm about 280 mm (70%) was contributed to the seasonal water use as an effective rainfall. The data in Table 1 for the one irrigation treatment reveal that the mean depths of irrigation added were reasonably equal when considering the soil heterogeneity and effect on estimation of available soil water. Similar trend was also depicted for the 2, 3 irrigations and rainfall only treatments. The total seasonal water use for the irrigation treatments was summarized in Table 2. Water added in 1, 2 and 3 irrigations treatments amounts to 4,475, 5,302 and 6,035 $m^3$/ha, which supplmented that added by rainfall only (3660 $m^3$/ha) by 23, 45 and 65%, respectively. The application of irrigation water in the presence of FYM showed minor differences, which an indication of accuracy in profile soil water estimation and irrigation water delivery (last column of Table 2).

**Table 1 Seasonal water use calculation sample for one irrigation treatment.**

| Rate of FYM(t/ha) | Effective rain (cm) | Added irrigation (cm) | Profile water content (cm) at | | Seasonal water use | |
|---|---|---|---|---|---|---|
| | | | Planting | Harvest | (cm) | $M^3$/ha |
| 0 | 27.95 | 13.57 | 7.78 | 4.21 | 45.05 | 4505 |
| 4 | 27.95 | 13.37 | 6.63 | 4.25 | 43.70 | 4370 |
| 8 | 27.95 | 14.23 | 5.49 | 2.07 | 45.60 | 4560 |
| 12 | 27.95 | 13.87 | 7.10 | 4.29 | 44.63 | 4463 |
| Mean | 27.95 | 13.76 | 6.75 | 3.71 | 44.75 | 4475 |

**Table 2 Mean total seasonal water use by sorghum plants ($m^3$/ha).**

| FYM(t/ha) | Irrigation regimes | | | | Mean |
|---|---|---|---|---|---|
| | None | One | Two | Three | |
| 0 | 3650 | 4505 | 5410 | 6140 | 4926 |
| 4 | 3600 | 4370 | 5380 | 5820 | 4793 |
| 8 | 3710 | 4560 | 5270 | 6250 | 4948 |
| 12 | 3680 | 4463 | 5150 | 5930 | 4806 |
| Mean | 3660 | 4475 | 5302 | 6035 | 4868 |

*4.2 Plant Growth*

Sorghum plant growth performance has been responsive to the soil and water management systems. There was an obvious improvement in the plant establishment and growth with supplementary irrigation and addition of FYM (Table 3). Both treatments have contributed significantly to plant growth (P < 0.01). Irrigating twice and three times gave better effect than irrigating once and no irrigation, while the effect of 4 and 8 t/ha FYM was approximately equal and were superior to zero and 12 t/ha.

*4.3 Grain Yield*

Sorghum crop yield as affected by the treatments was presented in Table 4. Mean grain yield was significantly increased with supplementary irrigation over the rain-fed cultivation, where 1919, 1870 and 1679 kg/ha were obtained for one, two and three irrigations treatments, respectively compared to control (878 kg/ha). Relatively lower yield obtained from the 3 irrigations treatment was probably due to water logging condition that occurred when the third irrigation in one season has coincided with heavy rains. As compatible with the result of plant growth, the 4 and 8 t/ha FYM treatments were remarkably increased the yield over the zero and 12 t/ha with high significant difference (P < 0.01). The mean yield increase (1586 kg/ha) due to effect of moisture plus organic manure amounts to 80% compared to rainfall alone (control). It is surprisingly that with 12 t/ha organic manure the yield was depressed. The table clearly indicates that the 12 t/ha under both one and no irrigation regimes provided the lowest yield. Probably, decomposition of this large amount of organic manure is not feasible with relatively less amount of irrigation times. Interaction between the irrigation and organic manure treatments was highly significant. None of the late season constraints was encountered during the three seasons' trials, specially the water stress. Eck and Musick [3] found that a water stress during vegetative and extends to mid-season reduced yields 36-54%.

Similar benefits of supplementary irrigation have been reported for rain-fed areas in Sudan, where yields are significantly increased and complete failure of

**Table 3 Effective of supplementary irrigation and organic farm manure on sorghum plant growth (cm).**

| FYM (t/ha) | Irrigation regimes | | | | Mean | SE(+) |
|---|---|---|---|---|---|---|
| | None | One | Two | Three | | |
| 0 | 73.3 | 110.0 | 162.7 | 196.7 | 135.7 | 4.8** |
| 4 | 78.0 | 123.3 | 183.3 | 212.3 | 149.2 | |
| 8 | 78.3 | 131.0 | 176.0 | 185.0 | 142.6 | |
| 12 | 73.0 | 108.7 | 133.3 | 169.7 | 121.2 | |
| Mean | 75.7 | 118.3 | 163.8 | 190.9 | 137.2 | |
| SE(+) | 5.3** | | | | | |

** The treatment means difference is highly significant at 0.01% level of significance.

**Table 4 Effect of supplementary irrigation and organic manure on sorghum grain yield (kg/ha).**

| FYM (t/ha) | Irrigation regimes | | | | Mean | SE(+) |
|---|---|---|---|---|---|---|
| | None | One | Two | Three | | |
| 0 | 713.3 | 2193.0 | 1434.0 | 1248.3 | 1397.2 | 153.2** |
| 4 | 1248.7 | 2564.3 | 4021.0 | 2210.0 | 2520.0 | |
| 8 | 803.3 | 2244.0 | 1113.3 | 1906.3 | 1516.7 | |
| 12 | 709.3 | 676.0 | 910.7 | 1349.3 | 911.3 | |
| Mean | 877.7 | 1919.3 | 1869.8 | 1678.5 | 1586.3 | |
| SE(+) | 457.4 * | | | | | |
| SE(+)Int. | 306.4** | | | | | |

* The treatment means difference is highly significant at 0.05% level of significance.
** The treatment means difference is highly significant at 0.01% level of significance.

Table 5 Effective of supplementary irrigation and organic farm manure on sorghum crop water use efficiency (kg/$m^3$).

| FYM(t/ha) | Irrigation regimes | | | | Mean |
|---|---|---|---|---|---|
| | None | One | Two | Three | |
| 0 | 0.20 | 0.49 | 0.27 | 0.20 | 0.29 |
| 4 | 0.36 | 0.59 | 0.75 | 0.38 | 0.52 |
| 8 | 0.22 | 0.49 | 0.21 | 0.31 | 0.31 |
| 12 | 0.19 | 0.15 | 0.18 | 0.23 | 0.19 |
| Mean | 0.24 | 0.43 | 0.35 | 0.28 | 0.33 |

crops was avoided [4]. Research conducted on sorghum in the central rain lands of Sudan by the same author and others showed that application of 8 combination of different supplementary irrigations at each of the three growth stages (planting to flowering, flowering to milk, and milk to maturity) yielded between zero to 3.9 t/ha for zero irrigation (rainfall only) to full irrigation.

*4.4 Water Use Efficiency (WUE)*

The amount of total seasonal water use was related to the grain yield to obtain the water use efficiency (WUE). The WUE or water productivity is simply computed as:

$$WUE = Yield/WU \tag{2}$$

Analysis of WUE result indicates appreciable increase with one and two irrigations compared to 3 irrigations and no irrigation (Table 5). The same trend and consistently produced by the 4 and 8 t /ha FYM with the plant growth and yield was prevailing here also. Under the irrigation treatments one, two and three, the sorghum plant consumed about 2.3, 2.8 and 3.6 $m^3$ of water to produce one kilogram of grain compared to 4.2 $m^3$ for non-supplementary treatment.

In two seasons of the three experimental seasons, rainfall is greater than the long-term average annual value. With supplementary irrigation early planting has been possible and enables about 70% of annual rainfall to be used effectively. However, under the normal traditional practice of flood irrigation effective uses never exceeds 45%, Omer [5]. Under such condition one to two supplementary irrigations with 4 t/ha organic manure seems sufficient to optimize the use of rainfall.

## 5. Marginal Economic Analysis

The economic analysis has indicated dominance of combination of 4 and 8 organic manure with two irrigations for sorghum production under supplementary irrigation. The marginal rate of returns was 156%.

## 6. Conclusion

The result asserts that irrigation is the most critical factor for sorghum production in EAS and preferably to be given at early and mid season times. Early planting and crop establishment facilitated by the provision of supplementary irrigation has maximized the use of rainfall to reduce the late season water stress and hence the need for a third irrigation. The result of such research has been adopted by the FAO Food Security project in Kordofan for expansion of food security activity in Abu Habil area. The project records showed that season (2004-2005) had remarkable productivity improvement with good impact in household food security despite of below average rainfall.

## References

[1] R. Lal, Managing the soil of Sub-Saharan Africa, Science 236 (1987) 1069-1073.

[2] J.F. Stone, J.E. Garton, B.B. Webb, H.E. Reeves, J. Keflemariam, Irrigation water conservation using wide-spaced furrows, Soil Sci. Soc. Am. J. 43 (1979) 407-411.

[3] H.V. Eck, J.T. Musick. Plant water stress effects on irrigated grain sorghum. I. Effects on yield, Crop Science Society of America 19 (1979) 589-592.

[4] S.M. Farah, Effect of supplementary irrigation on rain-grown sorghum (sorghum bicolor L.) in the Sudan, J. Agric. Sci. Camb. 100 (1983) 323-327.

[5] M.A. Omer, Effect of different irrigation beds and planting times on efficiency of irrigation water use in Khor Abu Habil, Annual Report (1994/1995) Agric, Research Corporation Wad Madani, Sudan, 1995.