

Research Application Summary

Improving water productivity of mango trees under different irrigation water regimes

Adam, B.A.,^{1*} Ibrahim, S.A.¹ & Elamin, A.W.M.²

¹Department of Agricultural Engineering, Faculty of Natural Resources and Environmental Studies,
Alsalam University, Sudan

²Department of Agricultural Engineering, Faculty of Agriculture, University of Khartoum, Sudan

***Corresponding Author:** adambush99@gmail.com

Abstract

In Sudan, mango trees (*Mangifera indica*) are irrigated through conventional basin system and therefore a huge quantity of water is lost in this traditional method. So to minimize these losses, drip irrigation system was designed, managed and followed. The experimental works were conducted at the Farm of AL Zawaia Group during two successive seasons (2017/2018 and 2018/2019) on sandy loam soil with the objective of investigating the effect of irrigation water regimes namely; 50%, 75% and 100% of crop evapotranspiration (ET_c) for improving water productivity of mango trees var. Tommy. A split plot design with three replications was used to in which drip irrigation and basin methods were laid in the main plot, while irrigation water regimes were assigned in the subplot. The parameters tested were irrigation systems performance, mango growth parameters, yield (kg/ha) and water productivity (kg/m³). SAS Package was used to analyze the collected data, while the means separation was by the Least Significant Difference (LSD) test. The findings indicated that drip irrigation gave the highest field performance and saved more than 30% of irrigation water as compared to flooded basin method. Moreover irrigation water regime of 75% ET_c significantly ($P \leq 0.05$) improved the growth parameters of mango trees, yield and water productivity followed by 100% ET_c. It is concluded that to enhance crop water productivity, managed drip irrigation system with deficit irrigation 75% ET_c should be adopted and followed.

Keywords: Drip irrigation, mango, Sudan, water deficit, water productivity

Résumé

Au Soudan, les manguiers (*Mangifera indica*) sont irrigués par un système traditionnel de bassin, ce qui entraîne une énorme perte d'eau. Afin de minimiser ces pertes, un système d'irrigation par goutte-à-goutte était conçu, géré et suivi. Les travaux expérimentaux étaient réalisés à la ferme du groupe AL Zawaia en deux saisons successives (2017/2018 et 2018/2019) sur un sol limono-sableux dans le but d'étudier l'effet des régimes d'irrigation, à savoir 50 %, 75 % et 100 % de l'évapotranspiration de la culture (ET_c), sur l'amélioration de la productivité en eau des manguiers de la variété Tommy. Un dispositif en parcelles divisées avec trois répétitions était utilisé, dans lequel les méthodes d'irrigation par goutte-à-goutte et par bassin étaient appliquées dans la parcelle principale, tandis que les régimes d'irrigation étaient utilisés dans la sous-parcelle. Les paramètres testés étaient : les performances des systèmes d'irrigation, les paramètres de croissance des manguiers, le rendement (kg/ha) et la productivité en eau (kg/m³). Le logiciel SAS était utilisé pour analyser les données collectées, tandis que des moyennes étaient séparées par le test de la différence significative la plus faible (LSD). Les résultats ont montré que l'irrigation par goutte-à-goutte a donné les meilleures performances sur le terrain et a permis d'économiser plus de 30

% d'eau d'irrigation par rapport à la méthode traditionnelle du bassin inondé. De plus, le régime d'irrigation à 75 % de l'ETc a significativement ($P = 0,05$) amélioré les paramètres de croissance des manguiers, le rendement et la productivité en eau, suivi du régime à 100 % de l'ETc. En conclusion, pour améliorer la productivité en eau des cultures, il convient d'adopter et de suivre un système d'irrigation par goutte-à-goutte géré avec un déficit de 75 % de l'ETc.

Mots-clés : Irrigation goutte-à-goutte, mangue, Soudan, déficit hydrique, productivité en eau

Introduction

A great challenge for the agricultural sector is to produce more food under the limitations of available water and climatic variations. To make efficient use of water, irrigation scheduling and managing are highly required to apply water at the right time with enough quantity of water and high irrigation efficiency. Therefore proper irrigation is required during critical stages of mango (*Mangifera indica*) growth and development so as to attain full sized fruits and avoid fruit drop of mango. Drip irrigation has a great potential for water saving and high application efficiency and productivity. Bush and Mohamed (2016) reported that drip irrigation significantly increased crop yield due to high irrigation performance and balanced moisture content root zone system with minimum water losses and it saved more than 30% irrigation water compared to conventional flooding irrigation method. Spreer *et al.* (2009) assessed the response of mango trees to varying amounts of available water, and their results indicated that the average fruit weight was increased and water was saved. So watering regime is one of key strategies for solving water shortage and conserving water without any negative impact on yield and fruit quality (Shaban *et al.*, 2020). Addressing water deficit at pre-flowering stage improved fruit yield and water productivity as mentioned by Faria *et al.* (2016). Dinesh *et al.* (2008) mentioned that, drip irrigation scheduling in mango with irrigation water regimes of 25%, 50%, 75% and 100 % ETc significantly increased canopy volume, fruit number and yield at 75% ETc, while 100% ETc increased fruit volume and moisture content. On the other hand, Waleed and Sayed (2017) reported that irrigation water regime of 85% ETc improved the yield and crop productivity of mango trees as compared to 50% ETc which ranked the least.

In Sudan, mango is traditionally irrigated through basins system with overall efficiency of not more than 45%. The farmers make small basins around mango trees and flood the trees by a small channel. So a huge quantity of water is lost through conveyance system and therefore the irrigation method does not meet total mango crop growth requirements, and hence, water supply is limited at critical stages and water productivity is very poor (Bush and Mohamed, 2016). So irrigation systems performance needs to be improved and irrigation water could be managed to minimize water losses and produce quality fruits, higher yields and thus improving water productivity. Therefore, this study investigated the effect of irrigation water regimes for improving water productivity of mango trees var. Tommy (*Mangifera indica*) under semi-arid conditions of Sudan.

Materials and Method

Experiments site. The experiment was conducted at the Farm of AL Zawaia Group during two successive seasons (2017/2018 and 2018/2019) on sandy loam soil and semi-arid conditions. Rainfall is irregular and usually occurs in the form of short intense thunder storms. This means that there is water deficit and hence crop production should be based on irrigation. Therefore, irrigation was scheduled according to the daily consumptive use of the mango tree.

Experimental design and statistical analysis. Mango trees (*Manifera indica*) Tommy cultivar were obtained from tissue culture and planted after seed bed preparation at 7m × 7m spacing. Two irrigation systems (drip and conventional basin) were designed, tested and managed to accommodate different treatments namely; 100% ET_c, 75% ET_c and 50 ET_c were used to irrigate the mango trees. These treatments were arranged in split plot experiment with three replicates and then SAS (Statistical Analysis System) computer program was used to analyze the collected data. The analysis of variance (ANOVA) was conducted to determine differences between treatments.

Soil physical properties. It was determined at the Laboratory of the Department of Soil and Environment Sciences, Faculty of Natural Resources and Environmental Studies, Alsalam University.

Field Measurements. Crop water requirement (mm/day); was derived from crop evapotranspiration and calculated according to FAO (2010).

$$ET_c = ET_o * K_c * K_s * K_r \dots\dots\dots (1)$$

Where:

ET_c = Crop evapotranspiration (mm/day); ET_o = Reference evapotranspiration (mm/day); K_c = Crop Coefficient (dimensionless); K_s = Soil water availability factor = 0.9 due to the soil type (clay loam); K_r = A reduction factor.

Reference crop evapotranspiration (ET_o) was determined by the following equation mentioned by Smith *et al.* (1998).

$$\frac{0.408\Delta(Rn - G) + \gamma \left(\frac{900}{T} + 273 \right) U_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34U_2)} \dots\dots\dots (2)$$

Where: ET_o = Reference crop evapotranspiration (mm day⁻¹); R_n = Net radiation at crop surface (Mj m⁻² day⁻¹); T = Average temperature at 2m height (°C); e_s = Svp, kPa e_a = Actual vp (kPa); (e_s - e_a) = Saturation pressure deficit for measurement at 2m height (kPa); U₂ = Wind speed at 2m height (ms⁻¹); γ = Slope of vapor pressure curve (k Pa °C); γ = Psychometric constant (k Pa °C); 900 = Coefficient for reference crop (Kj kg day⁻¹); 0.34 = Wind coefficient for the reference crop (S m⁻¹); G = Soil heat flux (Mj m⁻² day⁻¹).

Effective rainfall was defined as the fraction of rainfall that is effectively intercepted by the vegetation or stored in root zone and used by the plant as mentioned by Adam (2014):

$$P_{ef} = E. P_{tot} + A \dots\dots\dots (3)$$

Where:

P_{ef} = Effective rainfall over the growing season; E = Ratio of consumptive use of water (cubic) to P_{tot}.65; P_{tot} = Total rainfall over the growing season; A = Average application.

Depth of Applied Water: applied depth of irrigation water was calculated using the following equation stated by Parameshwarareddy *et al.* (2018) as follows:

$$Q * T = dg * A \dots\dots\dots (4)$$

Where: Q = applied discharge from the drip system (cm³/min.); T = time of irrigation (min.), A = wetted area (cm²); Dg = applied depth of water (cm).

The wetted area under the emitter was assumed to be circle in a shape.

Irrigation efficiency(IE); It is the effectiveness and the irrigation system in delivering the water beneficially used to produce the crop (Hamza and Almasraf, 2016).

$$IE = \frac{\text{Total water requirements}}{\text{Total applied water}} * 100 \dots\dots\dots (5)$$

Uniformity of water application (Cu): This was represented in ASAE standards (2008) as follows:

$$Cu \% = 100 \left[1 - \frac{1}{nqa} \sum_{i=1}^n |qi - qa| \right] \dots\dots\dots (6)$$

Where: q_a = the average emitter discharge rate (m³/s); q_i = the flow rate of the emitter (m³/s).

Emission uniformity (EU): was measured according to the equation stated by ASAE (2008):

$$Eu = \left[1 - \frac{127Cv}{\sqrt{n}} \right] \times \left[\frac{qn}{qa} \right] \times 100 \dots\dots\dots (7)$$

Where: q_n = the minimum flow rate of the sampling group emitters; q_a = the average emitter discharge rate (m³/s); Cv = the coefficient of variation of emitter flow

Mango growth parameters

Plant height (cm): was measured monthly on a random sample of ten plants per submain line. A measuring tape was used to measure the plant height from the ground surface to the tip of the plant. Number of leaves per plant; was counted monthly on a random sample of ten plants per submain line. Likewise, the number of leaves; was counted monthly from the random sample of ten plants per submain line. In addition, was measured using a measuring tape was used to measure the stem diameter (cm) from the ten plants randomly selected in each submain.

Water productivity (kg/m³): This is the outcome of an entire suite of plant and environmental processes operating over the life of a crop to determine both yield and water use. Yield is a measure of a crop's capacity to convert water into plant biomass or grain. The following equation was used for calculating the water productivity (FAO, 2010):

$$\text{water productivity} = \frac{\text{Yield(kg/m}^2\text{)}}{\text{Total depth of applied water (m)}} \dots\dots\dots (8)$$

Results and Discussion

Irrigation systems performance. Table 1 shows the irrigation system performance of drip and basin irrigation methods. Drip irrigation recorded the highest mean values of coefficient of uniformity (Cu%), emission uniformity (Eu%), scheduling uniformity (Su) and application efficiency (Ea%), while flooded basin method ranked the least. The superiority of drip system over the basin method may be due to the great potential of drip system in water saving and its ability to supply required amount of water at the right time with high application efficiency and productivity as confirmed by Ibrahim *et al.* (2012).

Effect of irrigation systems and different water regimes on growth parameters. As shown in

Table 2, drip irrigation significantly ($P \leq 0.05$) increased plant height, number of leaves and stem diameter in the two seasons of the study. On the other side, drip irrigation with irrigation water regime of 100% ETc provided mango trees with adequate daily consumption use at the root zone system so growth parameters developed and improved compared to flooded basin irrigation with 50%ETc. The results were in agreement with those reported by Dinesh *et al.* (2008).

As presented in Table 3 water productivity was significantly ($P \leq 0.05$) affected by the different irrigation systems and irrigation water regimes. Drip irrigation system followed by 75%ETc increased mango yield and water productivity as well as reduced water losses and saved more than 30% irrigation water as compared to basin irrigation system with 50% ETc. The results agreed with Rajesh *et al.* (2015) who indicated that drip irrigation system saved about 31% of water. The results also confirmed that, water deficit at pre-flowering stage improved fruit yield and water productivity as mentioned by Faria *et al.* (2016). Moreover, Waleed and Sayed (2017) found that, yield and water productivity of mango trees significantly improved under 85% ETc compared to 50% ETc which ranked the least.

Table 1. Irrigation systems performance

Irrigation systems	Irrigation system performance			
	Cu%	Eu%	Su	Ea%
Drip	88a	80 a	1.3 b	70.1 a
Basin	62 b	59 b	1.7 a	53.1 b
LSD	13.7	17.3	0.27	11.8

Mean values in column with same superscript letter show no significant difference as evaluated by LSD test at $P \leq 0.05$

Table 2. Effect of different irrigation systems and water regimes on growth parameters of mango

Treatments	Plant height (cm)	No of leaves	Stem diameter (cm)
Drip + 100% ETc	401 ^b	50 ^a	43 ^a
Drip + 75% ETc	450 ^a	52 ^a	44 ^a
Drip + 50% ETc	395 ^b	30 ^b	43 ^a
LSD	5.3	14.2	3.1
Basin + 100% ETc	370 ^b	45 ^b	43 ^a
Basin + 75% ETc	389 ^a	50 ^a	43 ^a
Basin + 50% ETc	360 ^b	48 ^a	42 ^a
LSD	13.1	3.1	2.3

Mean values in column share same superscript letter show no significant difference as evaluated by LSD test at $P \leq 0.05$

Table 3. Effect of different irrigation systems and water regimes on fruit yield (kg/tree) and water use efficiency (kg/m³) of mango

Treatments	Applied water (m ³ /tree)	Fruit yield (kg/tree)	Water productivity (kg/m ³)	Water saving (%)
		85.3 ^b	1.55 ^b	37
Drip+100%ETc	59.2 ^a	90.1 ^a	1.91 ^a	30
Drip+ 75% ETc	47.3 ^b	55.2 ^c	1.45 ^c	25
Drip+ 50% ETc	38.1 ^c	3.9	0.07	Average = 31
LSD	7.7	60.2 ^b	0.60 ^c	
Basin+100%ETc	90.3 ^a	66.7 ^a	1.11 ^a	
Basin+ 75% ETc	60.5 ^b	45.1 ^c	0.96 ^b	
Basin+ 50% ETc	47.2 ^c	4.8	0.12	
LSD	11.			

Mean values in column share same superscript letter show no significant difference as evaluated by LSD test at $P \leq 0.05$

Conclusion

In Sudan, irrigation practice depends more on the available water quantity and the farmer's experience rather than actual water requirement. So, there is an urgent need for modern irrigation systems to save water and enhance water productivity. Based on the results of this study, it is concluded that drip irrigation system with irrigation water regime of 75% crop evapotranspiration significantly increased mango yield and water productivity compared to flooded basin method.

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