Effect of micro sprinkler irrigation intervals on onion (*Allium cepa* L.) production compared to surface irrigation under Kassala conditions, Sudan

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ABSTRACT

An experiment was conducted to evaluate the effects of surface and micro sprinkler irrigation intervals on onion production under Kassala conditions. Three irrigation intervals were applied under micro sprinkler irrigation; every day, three days and at five days compared to farmers practice, (surface irrigation every 7 days). The treatments were replicated four times in a randomized complete block design. The results showed that higher yields were produced under micro sprinkler irrigation than surface irrigation. Moreover, micro sprinkler every day recorded the highest yield in both seasons. Therefore, micro sprinkler irrigation system was saving water by about 119% and 101% for seasons one and two, respectively, as compared to surface irrigation. The highest values of water productivity and economic water productivity were obtained under micro sprinkler irrigation system every day as compared to surface irrigation. Irrigation every day under micro- sprinkler irrigation was the most economic and had higher net benefit compared to surface irrigation.

INTRODUCTION

In Sudan, irrigation is playing a major role in agricultural production. Large amounts of water for irrigation are lost by seepage, deep percolation, surface runoff and evaporation. The uncontrolled water application methods usually lead to huge losses of irrigation water (Adam, 2006).

Kassala city is located in eastern Sudan (latitude 15° 45´ N, longitude 36° 38´ E and altitude is 505 masl) and it is a big region of onion production in the Sudan, where the cultivated area is estimated as 10,000 ha giving a total yield of 360,000 tons; which represent about 80% of the vegetable area in Kassala State (Horticulture Administration, 2013). However, Kassala recently gained an increasing importance in onion production, especially for early winter production. In recent years, there is an increasing interest in the production of onion in large areas for both traditional home market and for export (Horticulture Administration, 2013).

Micro sprinklers are low capacity water emitters, sprinkler in type, but smaller in size than the conventional sprinklers and with flow rates up to 250 l/h. They are placed on a relatively close rectangular or triangular spacing for the maximum overlap to irrigate crops. This method is reliable, highly efficient, and easy to apply, operate and handle (Michael, 1978). Micro sprinkler irrigation requires less energy, less pressure and low discharge. There is no runoff problem on the soil surface as well as no deep percolation problems. Visual inspection of the micro sprinklers is simple and fast. Less time is required for the inspection as compared to several emitters per tree in a drip irrigation system (Rathod, *et al*., 2006).

Many research workers observed increased crop yield in micro sprinkler irrigation system. Anand, *et al*. (2012) reported that micro sprinkler irrigation system performed better in terms of yield, plant height and reduced cost compared to surface irrigation of tomato. Moreover, Srivastava and Chauhan (1999) recorded the highest yield of cabbage in micro sprinkler irrigation (40.23t/ha) followed by drip irrigation (38.97t/ha) and surface irrigation (33.54t/ha).

The high crop water requirement in Kassala is a big problem for cultivation with the limited water supply from the existing aquifer (R.A.U.W.V, 2009). However, underground water can be used to irrigate areas where there is a possibility to produce valuable crops. Uses of modern irrigation systems can maximize utilization of the limited quantity of available water. The objective of this study was to evaluate the effects of a micro sprinkler irrigation system on onion production compared to surface irrigation in Kassala State, Sudan.

MATERIALS AND METHODS

The experiment was carried out at the Horticultural Administration Farm of the Ministry of Agriculture, Forestry and Irrigation, Kassala State, Sudan, during seasons 2014/15 and 2015/16 (latitude 15° 27´ N and longitude 36° 24´ E). The average elevation of the area is 500 masl. The climate of the area is semi-arid with most of the rainfall between July and October. The soil type is silt loam to silt-clay loam in texture.

A system of a micro sprinkler irrigation was installed. It consisted of a pump (I inch and 1 horse power), filter (1inch diameter), main and submain (32mm diameter), micro sprinkler lines (13mm diameter), micro sprinklers (50l/hr), connectors and end plugs. The system works with 1m high tank (2000 liters capacity). The system was installed and tested to irrigate the area of the experiment.

Quantity of irrigation water for these intervals was applied according to water requirement of onion at each stage.

Meteorological data including maximum and minimum air temperature, relative humidity, sunshine duration and wind speed at 2 meter height was taken from Kassala Meteorological Station and used for estimation of reference evapotranspiration (ETo) during the study period.

Crop evapotranspiration (ET_c) was calculated using the following formula:

$$ET_c = ET_0 \times Kc \ldots\ldots\ldots (1)$$

where

ET_c=Crop evapotranspiration (mm/day), K_c=Crop coefficient (dimensionless) and ET_0 =reference evapotranspiration (mm/day).

The standard K_c of every growth stage (initial, mid, and end) for onion was taken from the FAO 56 table 12 (Table 1), and adjusted to local information using the following equation according to Allen, *et al*. (1998):

$$K_{ci} = K_{c\,prev} + \left[\frac{i - \sum(L_{prev})}{L_{stage}}\right](K_{c\,next} - K_{c\,prev}) \ldots\ldots\ldots (2)$$

where

i =day number within the growing season, $K_{c\,i}$ =crop coefficient on day I, L_{stage} =length of the stage under consideration [days] and $\sum(L_{prev})$ =sum of the lengths of all previous stages [days].

Table 1. Onion crop coefficient.

Crop	K_c ini	K_c mid	K_c end
Onion	0.7	1.05	0.75

Source: (Allen, *et al*., 1998)

Table 2. Adjusted crop coefficient and growth stage of onion in Kassala.

Crop stage	Duration (days)	K_c (adjust)
Initial	30	1.05
Development	31	1.08
Mid	31	1.43
End	28	0.97

Volume of water to be applied was calculated according to Bagali, *et al*. (2012) using the following equation:

Quantity of water to be applied (litres) = ET_c (cm) x area (ha) x100000 ..(3)

The irrigation water was added to each treatment in the morning and the time of irrigation was calculated using the following equation:

$$\text{Irrigation time (hr/day)} = \frac{\text{Water requirement (l/day)}}{\text{Application rate (l/hr)}} \quad \ldots\ldots\ldots\ldots \quad (4)$$

The crop water requirement (CWR) for every micro sprinkler irrigation interval was calculated using the following equation:

$$CWR = ET_c \times (1, 3 \text{ and } 5 \text{ days}) \quad \ldots\ldots\ldots\ldots \ldots (5)$$

Table 3. Monthly reference evapotranspiration (ET_o) and crop evapotranspiration (ET_c) for onion crop at different stages during the two seasons

Month	2014/15		2015/16	
	ET_o	ET_c	ET_o	ET_c
	(mm/day)			
November	5.4	5.67	5.6	5.88
December	4.9	5.29	4.6	4.97
January	4.9	7.01	4.8	6.86
February	6.9	6.69	5.6	5.43

After transplanting, up to the seventh day, common irrigation was provided daily to all the treatment plots for uniform initial establishment of the crop and it was included while computing the total water applied to respective treatments. Three irrigation intervals were applied under micro sprinkler irrigation as follows: Every day, three days and five days compared with farmers practice (surface irrigation), every 7 days. Flowmeters were used for measurement of total water applied in both micro sprinkler and surface irrigation systems. The treatments were replicated four times in a randomized complete block design and the plot area was 5×5m. Three meters were left between all treatments to protect them from water leakage.

Onion Baftaim cultivar, was transplanted in the field on November 1st at the recommended spacing of 10×5cm. All cultural practices were carried out as recommended by Agricultural Research Corporation. The measured parameters were: total yield (ton/ha), marketable yield (ton/ha) and quantities of water applied in both irrigation systems.

Water productivity (WP) was calculated as the ratio of the crop yield to seasonal irrigation water applied using the following formula.

$$WP\ (kg/m^3) = \frac{\text{Yield (kg /ha)}}{\text{Total water applied } (m^3/ha)} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (6)$$

Economic water productivity (EWP) was calculated as the gross income in Sudanese Pounds (SDG) per gross water supplied in m^3 using the following equation:

$$EWP = GI/GIWR \quad \ldots\ldots\ldots\ldots\ldots\ldots (7)$$

where:

GI is gross income from the sale of onion (SDG/ha) and GIWR is gross irrigation water applied (m^3/ha).

Economic indicators such as partial budget and benefit cost ratio were used to evaluate and compare the profitability of the tested factors as described by (CIMMYT, 1988). Total income was calculated by multiplying crop yield (t/ha) by crop value. Crop value was taken at 1500 and 2000 SDG per ton for first and second season, respectively, from Kassala local market and then used the average crop value for two seasons.

CropStat statistical program was used for data analysis and the least significant difference test was used for means separation at the probability level of 0.05.

RESULTS AND DISCUSSION

Effect of surface and micro sprinkler irrigation intervals on total and marketable yield

The effect of irrigation treatments showed very highly significant differences on total and marketable yields in the both seasons (Table 4). Micro sprinkler irrigation intervals every day, 3 days and 5 days increased marketable yield by 101%, 44% and 27% and 74% 58% and 36% for season one and two, respectively, as compared to the surface irrigation (Table 4). These results revealed that higher yields were obtained under micro sprinkler irrigation and the lowest under surface irrigation. Anand, *et al*. (2012) found that yield of tomato was highest in the micro sprinkler treatment and lowest in the surface treatment.

Micro sprinkler every day recorded the highest onion yield in both seasons (Table 4) which indicated that yield was affected by irrigation interval. Daily irrigation interval guarantees continuous availability of moisture in the crop root zone. This maintains the best soil physical conditions for plant growth by maintaining optimum soil-water-balance around plant roots. These results agree with those of Bagali, *et al*. (2012) who reported that irrigation schedule at daily interval recorded significantly higher bulb yield over other irrigation intervals. Moreover, many researchers reported that bulb yield of onion increased significantly with shorter interval of drip irrigation. Mustafa and Mohamed (2008) reported that higher strawberry yield was recorded every one and two days intervals under drip irrigation system. Moreover, El-Boraie, *et al*. (2009) stated that applying irrigation everyday produced the highest groundnut yield.

Table 4. Effect of surface and micro sprinkler irrigation intervals on total and marketable yield (t/ha) of onion production in Kassala during seasons 2014/15 and 2015/16.

Irrigation treatments	Total yield (t/ha)		Marketable yield (t/ha)	
	2014/15	2015/16	2014/15	2015/16
Micro sprinkler every day	50	58.3	43.5	51.8
Micro sprinkler every 3 days	36	51.8	31	46.8
Micro sprinkler every 5 days	36	48.8	27.5	40.3
Surface irrigation	23.3	32.7	21.6	29.7
Significant level	***	***	***	**
$SE^{\pm}$	2.4	3	2.3	3.6
CV%	13	12.5	15.2	17

** and *** : indicated significance at P≤ 0.01 and P≤ 0.001, respectively.

Effect of surface and micro sprinkler intervals on total water applied

The quantities of water applied to onion by micro sprinkler irrigation system and surface irrigation were 7267m^3/ha and 15895m^3/ha for season one and 8287m^3/ha and 16627m^3/ha for season two, respectively (Fig.1). Therefore, the percentages of applied water saving by micro sprinkler irrigation system were 119% and 101% for season one and two, respectively, as compared to surface irrigation. Similar results of saving irrigation water by drip irrigation system were reported by Mohammad *et al*. (2010) who found that drip and sprinkler irrigation methods were more effective and efficient than surface irrigation. Khalifa *et al*. (2013) found that drip irrigation system saved irrigation water of banana by 74% and 72% for the mother crop and first ratoon, respectively, compared to surface irrigation. Aujla *et al*. (2007) reported a saving of 25% water on drip irrigation as compared with furrow irrigation.

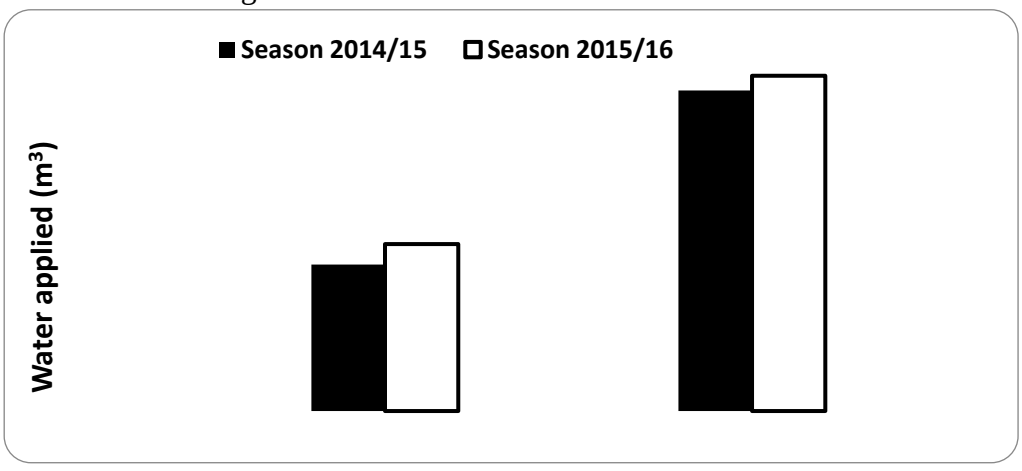

Figure 1. Effect of surface and micro sprinkler irrigation intervals on total water applied of onion (m^3) during seasons 2014/15 and 2015/16.

Effect of surface and micro sprinkler intervals on water productivity (WP) and economic water productivity (EWP)

The highest values of water productivity and economic water productivity were obtained under micro sprinkler irrigation system everyday. The irrigation water productivity was higher for micro sprinkler irrigation treatments compared to surface irrigation (Figs .2 and 3). These results are in agreement with those reported by Khalifa *et al*. (2014a) who stated that the highest values of water productivity and economic water productivity were obtained under drip system and the lowest under surface irrigation. All treatments under micro sprinkler system obtained the highest value of water productivity and economic water productivity compared to surface irrigation method. The highest water productivity and economic water productivity were obtained with micro sprinkler every day (Figs.1 and 2). Effects of irrigation intervals under modern irrigation system on water use efficiency were reported by El-Hendawy *et al*. (2008) who found that water use efficiency increased with increasing irrigation frequency and reached the maximum values at once every 2 and 3 days. Moreover, Al-Omran *et al*. (2005) reported that water use efficiency values increased linearly with applied irrigation water and decreased at the highest irrigation level.

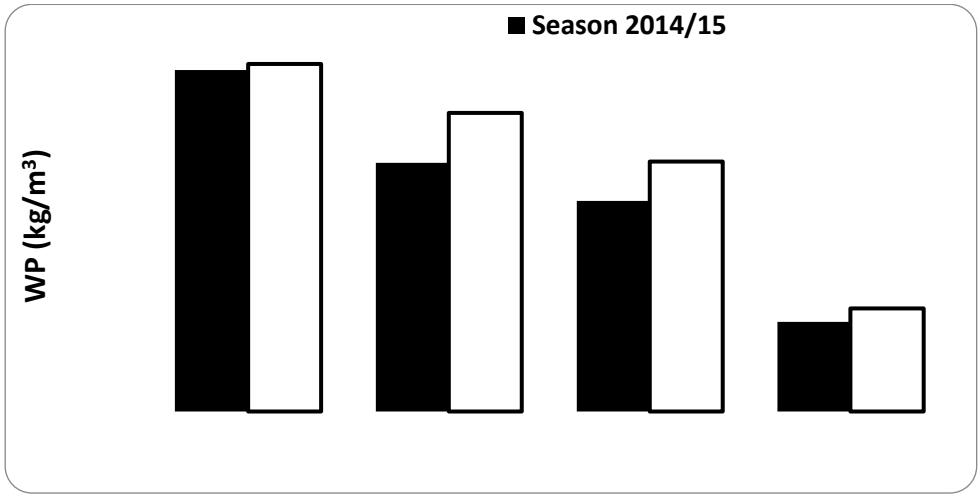

Figure 2. Effect of surface and micro sprinkler irrigation intervals on water productivity of onion (kg/m^3) during seasons 2014/15 and 2015/16.

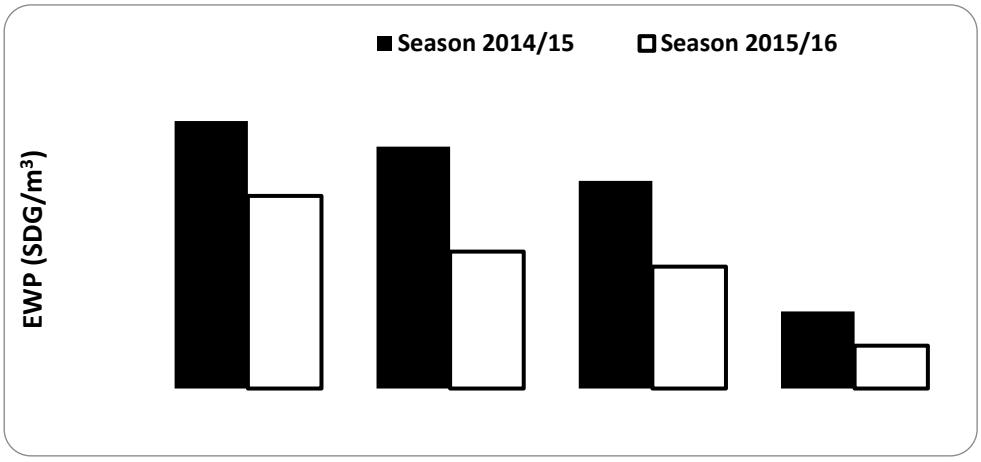

Figure 3. Effect of surface and micro sprinkler irrigation intervals on economic water productivity of onion (SDG/m^3) during seasons 2014/15 and 2015/16.

Effect of surface and micro sprinkler intervals on economic analysis

Variable costs of the irrigation system (micro sprinkler and surface) for onion are shown in Table 5. The benefit cost ratio showed that irrigation everyday under micro sprinkler irrigation is the most economic and had higher net benefit compared to other treatments (Table 6). These results are in agreement with those reported by Khalifa (2012), Khalifa *et al*. (2013) and Khalifa *et al*. (2014b). Moreover, Khalifa *et al*. (2014a) found that the highest net returns and benefit cost ratio were obtained in drip irrigation and the lowest were obtained in surface irrigation. On the other hand, Basavarajappa *et al*. (2010) reported that highest net returns and benefit cost ratio were obtained in the drip irrigation and the lowest were obtained in the furrow irrigation treatment.

Table 5. Variable cost of the surface and micro sprinkler irrigation intervals of onion in Kassala during 2014/15 and 2015/16.

No	Particulars	Treatments			
		Micro sprinkler			Surface irrigation
		Every day	Every 3 days	Every 5days	
1.	Variable cost (SDG/ha)				
	Irrigation system	11500	11500	11500	0
	Irrigation man power	2500	2250	2000	5000
	Fertilizer application	0	0	0	500

	Canals maintenance	0	0	0	1750
	Power (SDG/ha)	2160	2160	2160	5760
	Land preparation	1500	1500	1500	3600
	Hand labor	1056	1056	1056	1800
2.	Total cost (SDG/ha)	18716	18466	18216	18410

Table 6. Benefit cost ratio of the surface and micro sprinkler irrigation intervals of onion in Kassala during 2014/15 and 2015/16.

Irrigation Treatments	Average yield (t/ha)	Gross return (SDG/ha)	Variable cost (SDG/ha)	Net return (SDG/ha)	B/C Ratio (%)
Micro sprinkler every day	48	84000	18716	65284	3.5
Micro sprinkler every 3days	39	68250	18466	49784	2.7
Micro sprinkler every 5days	34	59500	18216	41284	2.3
Surface irrigation	26	45500	18410	27090	1.5

CONCLUSION

The highest yield, water productivity, economic water productivity and benefit cost ratio of onion were obtained under micro sprinkler everyday compared with surface irrigation.

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اثر فترات الري بالرش الدقيق علي انتاج البصل مقارنة بالري السطحي تحت ظروف كسلا، السودان

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الخلاصة

اجريت التجربة لتقييم أداء الري السطحي و فترات الري بالرش الدقيق لإنتاج البصل تحت ظروف كسلا. تم تطبيق ثلاث فترات ري تحت الري بالرش الدقيق على النحو التالي: كل يوم وثلاثة أيام وخمسة أيام مقارنة بممارسات المزارعين (الري السطحي) كل 7 أيام. تم تكرار المعاملات أربع مرات في تصميم القطاعات العشوائية الكاملة. أظهرت النتائج أن أعلى انتاجية كانت تحت الري بالرش الدقيق مقارنة مع الري السطحي. وعلاوة على ذلك، سجل الري بالرش الدقيق كل يوم أعلى انتاجية في الموسمين. نظام الري بالرش الدقيق وفر مياه الري بنسبة 119٪ و 101٪ للموسم الأول والثاني، على التوالي مقارنة بالري السطحي. وقد تم الحصول على أعلى قيمة لإنتاجية المياه وإنتاجية المياه الاقتصادية تحت نظام الري بالرش الدقيق كل يوم مقارنة بالري السطحي. الري يوميا تحت الري بالرش الدقيق هو الأكثر اقتصادا وله صافي فائدة أعلى مقارنة بالري السطحي.