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A Comparative Study Between Drip and Furrow Irrigation Systems in Open Field Radish Cultivation in Shambat Open Fields, Sudan

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ABSTRACT

This study was carried out to investigate the effect of drip irrigation on radish production in comparison with furrow irrigation under the open field conditions of Shambat. Drip and furrow irrigation systems were installed and evaluated in the Demonstration farm of the Faculty of Agriculture, University of Khartoum, during the winter season. Water requirements of the plant were calculated according to Penman-Monteith equation. Four levels of irrigation water were used (2520 m^3/ha/month), (1260 m^3/ha/month) and (315 m^3/ha/month) for drip irrigation system, (3600 m^3/ha/month) for furrow irrigation method. The radish crop was planted as an indicator plant on ridges 1 meter apart and at 50 cm spacing between plants. A completely randomized design was followed. The highest yield obtained was (2604 Kg/ha) for drip irrigation using (2520 m^3/ha/month) while the yield of (1659 Kg/ha) was obtained from Furrow irrigation using (3600 m^3/ha/month). The highest water use efficiency was 11.8 Kg/mm/ha for drip irrigation using (2520 m^3/ha/month), while the water use efficiency was 7 Kg/mm/ha for Furrow irrigation using (3600 m^3/ha/month).

KEYWORDS

Furrow irrigation, Drip irrigation, Water use efficiency, Crop water requirement

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INTRODUCTION

Water is increasing becoming a very scarce. If farmers want to ensure their survival in the future, they must employ and adhere to stringent water conservation methods. Irrigation has played and will continue to play a critical role in agriculture development. Irrigation has often been defined as the artificial application of water to soil to supplement that from rainfall for maximizing production per unit input. The purpose of irrigation generally is to facilitate the growth of crops to increase yields in areas where there is no enough rainfall for crop growth. In many arid and semiarid areas of the world, amount and timing of rainfall are not adequate to meet the moisture requirements of crop and irrigation essential to raise crops necessary to the needs of food and fibre. Areas requiring irrigation are very extensive and encompass portions of every continent of the world. The increasing demand for crop production to satisfy the needs of growing population is causing rapid expansion of irrigation throughout the world. Water being a limited resource, the efficient use of which is basic to the survival of the ever-increasing population of the world (Michael, 1978).

Sudan farmers are still using traditional surface irrigation systems in irrigating their crops. These systems are characterized by low efficiency due to losses by seepage, evaporation, run off, deep percolation and over irrigation. This low efficiency leads to high cost of irrigation and water shortage. Also, the labour cost of irrigation is very high compared with modern systems of irrigation such as drip irrigation system, which has a high efficiency and minimum water losses. These traditional systems consume much water and need large areas of land to construct small channels for irrigation and drainage. Water is becoming the most critical element in producing field crops, as the demands for water supplies are steadily increasing. Under such conditions, proper water control and using modern irrigation systems like drip irrigation save water to irrigate more agricultural lands, help to prevent salt accumulation, excess water logging and avoid weeds problems. The increasing need for crop production for the growing population is causing rapid expansion of irrigation throughout the world. And water is increasingly becoming a very scarce resource. So, if farmers want to insure their survival into the future, they must employ and adhere to stringent water conservation methods. Drip irrigation is not commonly used in crop production in Sudan. It may be used in private small farms, gardens and in green houses. Ahmed (1991) surveyed some areas in Sudan which could be adapted to drip irrigation for their soil characteristics and lack of water as The Northern State, North of Kordufan and Darfour States to produce valuable crops.

Drip was born in Germany in 1869 where subsurface irrigation was performed in combination with drainage systems, in which short porous clay pipes were used. In 1912 the first subsurface drip irrigation was reported using metal pipes in U.S.A., but it was highly expensive as being practical. In 1925 to 1932 some experts in France and Russia used subsurface drip irrigation. In England it was used between 1945 to 1948 to irrigate tomato plants in greenhouses. Technological development of plastic pipes after the second world war made the use of drip irrigation system practical. Micro irrigation research began in Germany about 1860 and in the 1940th, it was introduced to England especially for watering and fertilizing plants in greenhouses. With increased availability of plastic pipe and the development of emitters in Israel in the 1950s, it has since become an important method of irrigation in Australia, Europe, Israel, Japan, Mexico, South Africa and the united states (Schwab et. al, 1993).

The major advantage of drip irrigation systems is that the close balance between applied water and crop evapotranspiration reduces surface runoff and deep percolation to a minimum. For perfect drip irrigation system design, about 40 % of the irrigation water is saved with an application efficiency of 85% to 95% as compared with other irrigation systems. Drip systems produce higher ratio of yield per unit area and yield per unit volume of water than typical surface or sprinkler irrigation systems (Cuenca, 1989). Labour requirement are lowered, and the system can be readily automated (Abbas et. al, 1992). Frequent or daily application of water keeps the salts in the soil water more dilute and leached to the out limits of the wet zone to make the use of saline water more practical (Jensen, 1983). Weeds growth is reduced because of the limited wet soil surface (Lateif et. al, 1988). Use of drip irrigation is practical even in fields that have 5 to 6 % slope without erosion (Khalil, 1998). Drip irrigation needs no levelling, no drainage and no other field operations like ridging. Fertilizers and chemicals can be injected into the irrigation water causing a uniform distribution at the root zone (Al Amound, 1997). Bacteria, fungi and other pests and diseases that depend on moist environment are reduced, as the above ground plant parts are normally completely dry (Schwab et. al, 1993). Landscape is the area where drip irrigation is experienced it would widely suit many landscape situations, balancing the high and rapidly rising cost of water and pumping energy. The environment is kept sound by not allowing chemicals (fertilizers, pesticides and herbicides) to run deep and penetrate the soil to affect ground water.

The major disadvantage of the system is its high capital or initial cost (Michael, 1999). Clogging of emitters by biological, chemical and physical matters is very prominent Frequent application of water leach the salts out to the limit of the wetted zone, if system stops supplying water, the salts may enter to the root of the plant causing wilting or poisoning of the plant (Abd Elazeem, 1997). It is only suitable to be used with crop with shallow roots due to the limited wet zone. The field needs frequent irrigation and in case of trees they are liable to tilt in the windward direction and may be uprooted.

This study is conducted with a view to achieving the following objective: Comparison between drip irrigation system and furrow irrigation method for Radish crop production with special reference to crop yield and yield components, water distribution uniformity and water use efficiency (WUE).

MATERIALS AND METHODS

Experimental Site Description

The experiment was conducted during the month of January to February 2007 in the demonstration farm of the Faculty of Agriculture, University of Khartoum, Shambat at latitude 15° 40\` N, longitude 32° 32\` E and altitude 380 m above mean see level.

The climate of the area is tropical semi-arid. It is characterized by low relative humidity, with mean daily maximum and minimum temperatures of about 36ºC and 21ºC, respectively. The annual rainfall is about 158 mm mainly during July, August and September. The soil of the experimental field is heavy clay with percentage ranging between 65% in the top 15 cm and 55% in the 100 to 140 cm profile. The soil reaction is moderately alkaline with pH ranging from 7 to 8 (Saeed, 1968). The infiltration rate is low and has been estimated to be about 20 mm/hr. in the first two hours and 5 mm/hr. after 10 hours (Ferguson, 1970). The area size of the experimental pot was 86 m^2. The treatment included two different irrigation methods, drip and furrow irrigation systems. The experimental design adopted was the completely randomized design. Radish crop had been selected as an indicator plant because the plant is sensitive to watering regimes. could be grown in rows and easily irrigated by drip system, and a winter crop which matches the time this study was to be conducted.

The installed drip irrigation system ran on a 1.0 kW centrifugal pump unit which was operated by 1.1 kW electric motor and was utilized to draw water from the main line of the Shambat supply system. Two control valves were fixed one before the pump unit and the other after it. A disc filter was used to clean the water. **A** pressure regulator was used to control the pressure in the system. The main pipe line was made of polyvinyl chloride (PVC). The PVC pipe was buried under ground at a depth of 50 cm. The main line was 30 m long and 50 mm diameter. The sub main pipe was also made of polyvinyl chloride (PVC). The sub main line was 12 m long and 25 mm in diameter. The sub main was buried at 30 cm under the ground surface. The lateral pipes were made of black linear low-density polyethylene (LLDPE). There were six laterals, each 10 m long and 16 mm inside diameter were joined to the sub main at 1 m spacing between laterals. On line emitters type were used in this system. The discharge of each emitter was 8 l/hr. Emitters were fixed in each lateral with 50 cm spacing, thus coinciding with the plant spacing.

The prepared furrow system consisted of 2 ridges, each 10 m long and 1 m spacing. Spacing between plants on the ridge 50 cm. Similar land preparation was carried out for both furrow and drip irrigation systems that involved disking, levelling and ridging. The field area was ploughed with a standard integral mounted disc plough at a depth of about 0.25 m. Then the land was levelled with a general-purpose blade. Finally, ridging was done at a spacing of 1 m with a general purpose ridger.

Table 1 presents the soil properties of the soil samples taken that were taken and analysed for the selected soil properties.

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Table 1: Selected properties of the soil samples taken from the experimental field area

pH	Field Capacity, %	Bulk Density, g/cm³	Particle, Density, g/cm³	Composition		
				Sand, %	Silt, %	Clay, %
7.5	32	1.35	1.9	15	30	55

Field Experiment

The experiment was conducted during 5th January to 20th February 2007. Three seeds of radish crop were planted manually in each of the prepared planting hole. These holes were in rows on the side of the ridge to give a spacing of 1 meter between ridges and 50 cm between plants.

The interval between irrigations was set at 7 days for the furrow method and daily for the drip system. Different amounts of water were applied for the furrow and drip irrigation systems. The four levels of irrigation water that were used are 2520 m³/ha/month, 1260 m³/ha/month, and 315 m³/ha/month for the drip system and 3600 m³/ha/month for the furrow system.

The planted radish crops were measured for the crop parameters during the 2nd, 3rd, 4th and 5th week of their growing stage. The measured crop parameters include number of leaves per plant, length of leaf, plant height and plant diameter. Mature crop was gathered, and samples were taken to measure the weight of root system and shoot system; to calculate yield and water use efficiency.

The water discharge rate of the furrow irrigation system was measured at the inlet furrow g right angle triangular weir and a Parshall flume. The water discharge rate of the drip irrigation system a graduated cylinder and a stop watch. The determination was repeated three times whenever any measurements on the water discharge were taken.

RESULTS AND DISCUSSIONS

Crop Water Requirement

Table 2 shows climatic data and the reference crop evapotranspiration (ETo) was then calculated. The mean monthly reference crop evapotranspiration (ETo) for two months was found to be 9.3 mm/day.

Table 2: Mean monthly meteorological data and mean monthly of reference crop evapotranspiration

Month	Mean Temperature, ºC		Relative Humidity, %	Wind Speed at 2m, m/s	Sun Shine, hours	ETo, mm/day
	Tmax	Tmin				
January	33.6	15.6	28	2.11	9.6	9.2
February	35.2	16.1	19	2.11	9.8	9.4

Where Tmax = maximum temperature, ºC; Tmin = minimum temperature, ºC and ETo = reference crop evapotranspiration.

Table 3 shows the calculated Radish water requirement for two months which represent the length of its growing season. It was found that the mean Radish water requirement (ETc) was 8.4 mm/day.

Table 3: Crop water requirement for Radish crop.

Month	ETo , mm/day	Kc	ETc, mm/day	ETc, mm/month
January	9.2	0.9	8.3	249
February	9.4	0.9	8.5	255

Where Kc = crop factor of Radish, proportion and ETc = crop evapotranspiration of Radish, mm/month.

Table 4 shows the mean monthly data of the total rainfall (TRF), the mean monthly effective rainfall (ERF) and the net Radish water requirement (NCWR) as calculated from the total rainfall data.

Table 4: Net radish water requirement

Month	ETc, mm/month	TRF, mm	ERF, mm	NCWR or ETC-ERF, mm/month	NCWR, m³/ha/month
January	249	0.0	0.0	249	2490
February	255	0.0	0.0	255	2550

Where TRF = mean monthly total rainfall, mm; ERF = mean monthly effective rainfall, mm and NCWR = net Radish water requirement, mm/month or m³/ha/month

Crop Agronomics

Figure 1 shows the test plots under with the crops under drip irrigation system and the crops under furrow irrigation system.

(a) Test plot with furrow system

(b) Test plot with drip system

Figure 1: Test plot under 2 different irrigation systems

The statistical analysis of the data is shown in appendix (D). It can be seen that the Radish plant agronomic parameters are significantly ($p \leq 0.05$) affected by irrigation method (drip and furrow). Tables 5 to 9 show a summary of the analyses.

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Table 5: Mean comparison test on 2nd week

Crop Agromics	Drip 2520, m³/ha/month	Drip 1260, m³/ha/month	Drip 315, m³/ha/month	Furrow 3600, m³/ha/month	LSD
Leaves number	2	2	2	2	0
Leaf length, cm	1.7	1.4	1	1.1	0.14
Plant height, cm	7	6	4	5	1.4
Plant diameter, cm	3.5	2.5	1.5	2	0.9

Table 6: Mean comparison test on 3rd week

Crop Agronomics	Drip 2520, m³/ha/month	Drip 1260, m³/ha/month	Drip 315, m³/ha/month	Furrow 3600, m³/ha/month	LSD
Leaves number	5.5	4	3	3	0.9
Leaf length, cm	5	4	2	3	1.4
Plant height, cm	8	6	4	5	0.9
Plant diameter, cm	10.5	9.5	3.5	7.5	1.9

Table 7: Mean comparison test on 4th week

Crop Agronomics	Drip 2520, m³/ha/month	Drip 1260, m³/ha/month	Drip 315, m³/ha/month	Furrow 3600, m³/ha/month	LSD
Leaves number	8	7	4	6.3	0.5
Leaf length, cm	8	6	3	5	1.4
Plant height, cm	9	7	5	6	0.9
Plant diameter, cm	17.5	15.5	7	12.5	1.7

Table 8: Mean comparison test on 5th week).

Crop Agronomics	Drip 2520, m³/ha/month	Drip 1260, m³/ha/month	Drip 315, m³/ha/month	Furrow 3600, m³/ha/month	LSD
Leaves number	9.5	8	4.5	7	1.4
Leaf length, cm	13.5	9.5	4.5	7	1.7
Plant height, cm	11	9	6	7	1.9
Plant diameter, cm	27.5	20.5	10.5	18	1.7

Table 9: Mean comparison test on 6th week

Crop Agronomics	Drip 2520, m³/ha/month	Drip 1260, m³/ha/month	Drip 315, m³/ha/month	Furrow 3600, m³/ha/month	LSD
Leaves number	12	9.5	4.5	7	1.7
Leaf length, cm	17.5	11.5	6.5	10	1.7
Plant height, cm	12	10	7	9	1.4
Plant diameter, cm	45	25.5	13.5	20.5	2.6

Crop Yield

Table 10 shows the Radish yield according to irrigation method and water quantity. The highest yield obtained was 2604 kg/ha for drip irrigation system using 2520 m³/ha/month, while for 1260 m³/ha/month it gave a yield of 1827 kg/ha.

The furrow irrigation method with 3600 m³/ha/month gave a yield of 1659 kg/ha. The lowest yield of 1176 kg/ha was obtained from drip irrigation system using 315 m³/ha/month. The reason which leads to highest yield for drip irrigation system was the availability of irrigation water with suitable quantity and at suitable time. Also, Table 10 shows the ratio of root system to shoot system. The highest ratio was 80% for drip irrigation system using 2520 m³/ha/month, and the lowest ratio was 57% for drip irrigation system using 315 m³/ha/month.

Table 10: Yield of Radish crop

Crop Parameter	Drip 2520, m^3/ha/month	Drip 1260, m^3/ha/month	Drip 315, m^3/ha/month	Furrow 3600, m^3/ha/month
Yield, kg/ha	2604	1827	1176	1659
Root system weight, gm	124	87	56	79
Shoot system weight, gm	154.5	114.5	98	128.5
Ratio of root system to shoot system, proportion	80%	75.9%	57%	61.5%

Water Use Efficiency

Water use efficiency was calculated. Table 11 shows water use efficiency according to irrigation method and water quantity. The highest water use efficiency was 11.8 kg/mm/ha for drip irrigation system using 2520 m^3/ha/month. The lowest water use efficiency was 4.9 kg/mm/ha for drip irrigation system using 315 m^3/ha/month.

Table 11: Water use efficiency

Treatments	Water use efficiency (kg/mm/ha)
Drip 2520 m^3/ha/month	11.8
Drip 1260 m^3/ha/month	7.8
Drip 315 m^3/ha/month	4.9
Furrow 3600 m^3/ha/month	7

CONCLUSIONS

From the results of this study the following conclusions can be drawn:

- Drip irrigation system produces relatively more yield per unit area and more yield per unit volume of water than furrow irrigation method.
- High water uniformity is achieved under drip irrigation system.
- The major problem of drip irrigation system was emitters clogging.
- Proper filtration should be used to avoid emitters clogging
- Irrigation should be in the early morning or in the evening to reduce water loss by evaporation.

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