Different Irrigation Methods for Okra Crop Production under Semi-arid Conditions

Abubaker B. M. A[1*], Mohammad Alhadi[2], Yu Shuang-En[1] and Shao Guang-Cheng[1]
[1]*Key Laboratory of Efficient Irrigation-Drainage and Agricultural Soil-Water Environment in Southern China, College of Water Conservancy and Hydropower, Hohai University, Nanjing 210098, China;* [2]*Department of Climate Change, UNESCO water institute, Inndyr 8140, Norway*

Abstract - Irrigation methods have significant impact on okra production. Okra is popular vegetable crop used in Sudan. A field study was conducted to compare the efficiency and performance of the Drip irrigation (DI) and the conventional Surface irrigation (SI) systems under the same conditions for producing okra. An open field DI was installed with laterals 40m apart and 1m spacing. Emitters were inserted at 40cm spacing. A nested experimental design was used with two replications. Three okra varieties were tested for their watering requirements and agronomic performance. The parameters measured included plant height, stem diameter, root length, root weight and yield production. The study included some soil properties, infiltration rate, crop water requirement, crop water use efficiency, and uniformity of water distribution for both systems. The okra agronomic parameters except root length and weight were significantly ($p \leq 0.05$) affected by DI and SI. There were no significant differences between okra varieties. Results showed that the uniformity of water distribution of the DI was relatively 81.4 % high. The water applied to crop was greater than the actual crop water requirement and the efficiency of the DI was 126.5 % over that of the SI. Maximum yield of 249.71kg ha-1 was obtained by using DI. Sandy clay loam soil with a relatively high infiltration rate of 1.8 cm h-1 that suits the DI system is recommended.

Keywords Okra, drip irrigation, surface irrigation.

1. INTRODUCTION

Surface irrigation (SI) method is the widely applied in Sudan, due to cost-effectiveness and low maintenance requirements but, the irrigation efficiency is low due to losses by runoff in the heavy soils and deep percolation in light soils. Low efficiency leads to increment in the cost of irrigation, labour and water shortage compared with the modern irrigation systems such as sprinkler and drip irrigation (DI) which has high efficiency and minimum water losses. DI is one of the recent irrigation methods used in improving crop production and it is becoming increasingly popular in areas with problems of water scarcity and salinity. Drip irrigation has considerable advantages over furrow or even sprinkler irrigation in terms of water application efficiency is capable to small and frequent applications of water has created interest among the farmers because of less water requirement, increased production and better quality production [1]. Water application scheduling is a critical issue for DI system efficiency evaluation, because excessive or inadequate irrigation reduces yield. The optimal use of irrigation can be characterized by the supply of sufficient water according to plant needs in the deeper soil layers [2]. The obstacle for the spread and adoption of the DI is capital cost, although growers may be able to recover their cost in few years under favourable yields and market conditions [3]. The DI method has not yet been employed for extensive large scale crop production in Sudan. Survey analysis revealed that DI system is adopted in some areas in Sudan for producing crops in green houses, small private farms and gardens [4]. Okra, a widely distributed crop is one of the oldest cultivated crops in many parts of the world with its origin from Ethiopia and Sudan [5],[6]. It is an important vegetable because it is rich in vitamins, folic acid, carbohydrates, phosphorus, magnesium, calcium, potassium and other minerals [7]. Okra production is estimated at 6 million tons per year in the world [8]. In Sudan it is estimated at 256,000 tons [9]. The total area and production of okra in Sudan is reported to be 21.500 ha and 11.90 t ha^{-1} respectively with 3.24 % share in world production. In Sudan, a number of local mixed cultivation, with Indian and American introductions, are grown in the irrigated areas. To meet the increasing demand on okra crop to satisfy the needs of the growing population in Sudan, Elsilait Agricultural Project (EAP) Khartoum initiated rapid expansion of irrigation throughout the cities. Determination of the required amount of water for okra crop irrigating is important for maximum plant production, better water saving and management practices, and it can be obtained from either DI or SI methods. Accordingly, this study is aimed to compare the DI and the conventional SI method for okra crop production in terms of distribution uniformity, water usage efficiency (WUE), yield and yield components, reference crop evapotranspiration and crop water requirement was conducted.

2. MATERIALS AND METHODS

2.1 Study area and field conditions

Field experiment was conducted at EAP scheme site, Khartoum north of Sudan (15°40′N and 32°32′E, with an elevation 382m above mean sea level). The climate is tropical semi-arid which is hot dry in summer and mild dry in winter with a great seasonal variation in temperature. Tests for soil texture of the experimental site are dominated by sandy clay loam comprising of 54.8% sand, 13.7% silt and 33% clay with pH of 7.8. Average values for field capacity, bulk density and permanent wilting point are 36%, 1.3 gm/cm^3 and 26% respectively. The experimental soil was prepared by disc plough followed by leveler and ridging for both irrigation systems. The study area is 8400 m^2 with natural slope and uniform of soil texture. A factorial complete block design was used for the two irrigation methods, (Fig. 1). Three okra (*Abelmoschus esculentus*) cultivars were selected for the study namely *Khartoumia spiny* (V1), *Pusa Sawani*' (V2) and *karary* (V3).

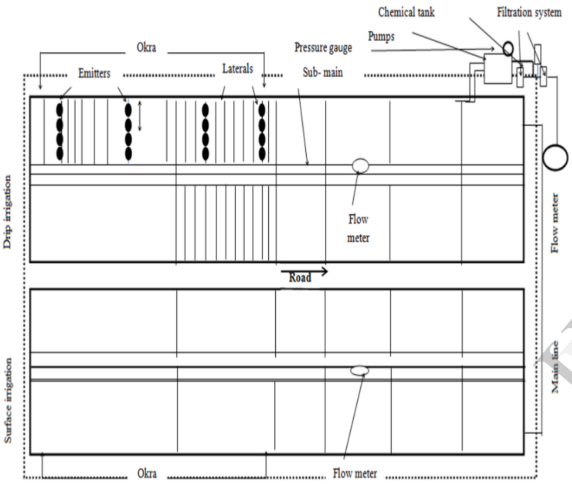

Fig. 1: Schematic of field experimental

2.2 System installation and experimental treatments

The DI system employed includes discharge valve, flushing valve, pressure regulator, screen filter, two sand filter and fertilizer injection with capacity of 100 litters. Two centrifugal water pump with 10, 5.5 hp capacity, driven by an electric motor was used to draw irrigation water from the storage tank at elevation of 12m in the supplying system. This set-up gave a pressure of 3 bars in the main line. The main pipeline is connected to sub-main pipelines of 240, 40m long and 63mm, 38mm in diameter respectively, and made of Polyvinyl Chloride (PVC). It was buried at a depth of 40cm. The lateral pipes are made of black Linear Low Density Polyethylene (LLDPE). The eighteen laterals is each 40m long and 16mm inside diameter. The laterals were joined to the sub-main at 1m spacing. The discharge from each emitter's is between 2-4 l/h as recommended by [10]. Emitters were fixed in each lateral at 40cm spacing that coincides with the plant spacing. Related to the SI method, the irrigation system is consisted of 2 ridges, 1m apart and 40m long. The spacing between plants on the ridges is 40cm.

2.3 Estimation of irrigation requirement and discharge measurement

Metrological data were collected from Sudan metrological authority as will be discussed later in details. Crop water requirement was calculated using the following formula [11]:

$$ET_C = ET_\circ \times K_C ,$$

where: ET_c: Crop water requirement (mm/day); $ET_\circ$: Reference crop evapotranspiration (mm/day); K_c: Crop coefficient.

Reference crop evapotranspiation ($ET_\circ$) was calculated according to Penman-Montieth, as suggested by [11]:

$$ETo = \frac{0.408\Delta(Rn - G) + \alpha \frac{900}{T + 273} U2(ea - ed)}{\Delta + \alpha(1 + 0.34U_2)}$$

where: $ET_\circ$: Reference crop evapotranspiration (mm/day); Rn: Net radiation at crop surface (MJ/m^2/day); G: Soil heat flux (MJ/m^2/day); T: Average temperature at 2 m height (°C); (ea−ed): Vapor pressure deficit for measurement at 2 m height; U2: wind speed at 2 m height (m/s); Δ: Slope of vapor pressure Curve (KpaoC); 900: Coefficient for the reference crop (kj/kg/day); 0.34: Wind coefficient for the reference crop (S/m); and Y: Psychometric constant (KPa oC).

The net crop water requirement (N_{CWR}) was calculated by subtracting the monthly effective rainfall (R_{ef}) from crop water requirement (CWR) as:

$$N_{CWR} = CWR - R_{ef}$$

The R_{ef}, (mm) was calculated from the total rainfall (TR) mm, according to the empirical formula suggested by USDA Soil Conservation Service [12] as:

$$Pe = C \times P_{tot} + d ,$$

where: Pe: Effective rainfall (mm/month); P_{tot}: Total rainfall in a given month (mm/month) and C, d are respectively, fixed percentage that accounts for losses from rainfall and deep percolation.

The datasets are also used to determine the amount of irrigation water required to bring the soil moisture content level in the effective root zone to field capacity. Ref. [13] proposed an equation to calculate the depth of water applied by considering the fact that only part of the soil volume has to be wet by DI as:

$$d = 10(Fc - PWP) \times D \times Z \times P$$

where: d: Maximum amount (depth) of water to be applied (mm); Fc: Field capacity (cm/m); PWP: Permanent wilting point (cm/m); D: Root zone depth (m); Z: The moisture depletion percentage allowed or desired (decimal) and P:

The volume of the wet soil is expressed as a percentage of total volume (in decimal). For the determination of the uniform distribution DI system, the discharge (q) was measured 70 emitter's chosen for each system, volumetrically using catch cans, and a stop watch. The equation by [14] was used:

$$Eu = \frac{qn}{q_{ave}} \times 100$$

The pressure was adjusted at 1bar for all the laterals. The measurements were repeated three times and then the average was taken. A regression analysis was used to analyze the rate of flow reduction along laterals. For the SI method discharge was measured using a right angle triangular weir and Parshall flume devices, based on the method developed by [15]. Three representative experimental sites were selected for measuring water infiltration in cm/hr following the procedure described by [16]. WUE of the crop for each treatment was computed from yield and water requirement data.

2.4 Yield data

Three seeds of okra were planted in each hole. The holes were in rows on the side of the ridge with spacing of 1m between ridges and 40cm between plants. Different amounts of water were applied for each furrow and drip irrigated. The interval between irrigations was 7days for SI and 3days for the DI. After one month of sow data was collected for both methods including plant height (cm), plant diameter (cm), root length (cm) and root weight (g). Nine picks for yield (kg/ha) was estimated considering the mean yield obtained from the replicated plots under the treatments then determination by using a sensitive balance. The total pods yield per hectare was estimated considering the mean yield obtained from the replicated plots under the treatments.

2.5 Data analysis

The data obtained from different experiments were recorded as mean ± standard deviation (SD) and subjected to one-way Analysis of Variance (ANOVA). Differences between means were considered significant at $P < 0.05$.

3.RESULTS AND DISCUSSION

3.1 Uniformity of Drip Irrigation

The results revealed that average discharge rate (q_{ave}) in emitters along laterals of the DI was 1.05 L/h. Average rate of discharge of the lowest one fourth of the field data (q_n) was found to be 0.85 l/h. Thus, the uniformity of DI was found to be 81.4% and that of the SI was between 50- 60% [17]. On the other hand the low water distribution efficiency in furrow may be attributed to water losses by evaporation, deep percolation and run off. The DI system greatly minimizes the losses of such factors and the results are in conformity to that by [15], [18]. Fig. 2 shows the relation between discharge (l/h) and distance (m) along the laterals of the DI method. Generally, there is a negative relation between the amount of water conveyed along the lateral line and the position of the lateral on the sub-main line. The correlation coefficient (r) is high −0.6 to −0.8 for those laterals which were within 0-18m for zones a-c along the sub-main line. However, this negative relation dropped to a moderate value of r = −0.38 for those laterals in zone d and then to a weak value of r = −0.23 for the laterals in the lowest part of the sub-main in zone e. The amount of water discharge to the SI indicated that the (r) was 0.42 (Fig. 3). These results agree with the opinion given by [19] who stated that the soil water distribution can be achieved by selecting the appropriate dripper discharge and spacing.

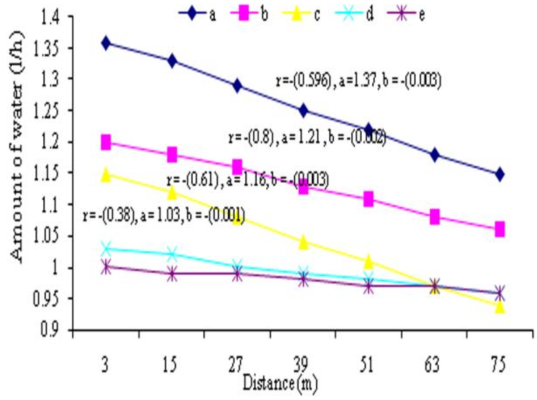

Fig. 2: Discharge rate of 70 emitters (l/h) on the different laterals along the sub-main line of DI

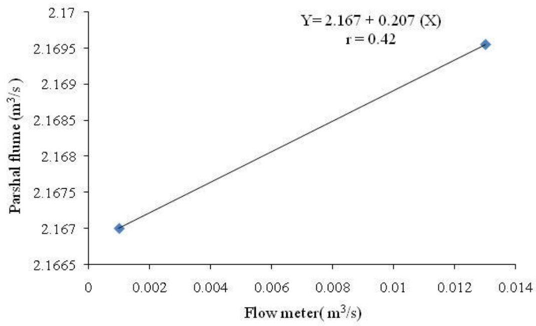

Fig. 3: The water discharge rate (m3/s) measured by flow meter and parshal-flume under SI

The results showed the water infiltration rate values were presented in (Fig. 4) the average of infiltration rate ranges between 1.1 - 1.8 cm/h. Hence the DI was observed to be suitable to soil properties which has high infiltration rate than the SI. The DI supports good plant growth and keep on replenishing the crop root zone which can be attributed to nature of the soil nature as it swells by the wetting phenomenon there by closing soil pores which greatly reduces and impede infiltration [20].

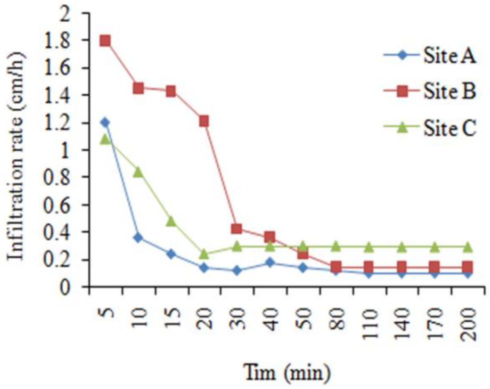

Fig. 4: Infiltration rate (cm/h) at three random sites of the experimental field

3.2 Crop water requirement (CWR) and water use efficiency (WUE)

Table 1 shows climatic data and the ET_o. The monthly mean reference of crop evapotranspiration was found to be 6.53 mm/day.

Ref. [8] stated that the water consumption is about 8 mm/day for full-grown crop. Table 2 shows the calculated okra water requirement for four months, which represents the length of its growing season. It was found that the mean okra ET_c was 5.1mm/day, and this result agrees with that of [21] found that there was a linear relationship between okra production and the amount of water supplied. Table 3 shows the monthly mean data of T_{RF}, and the okra N_{CWR}. Rainfall was not encountered during those months, the okra N_{CWR} coincided with ET_c. As it appears in Table 4, the DI generally showed higher crop WUE, as compared to SI. The efficiency of the DI was 126.5 % over that under the SI. This might be due to moisture conservation under DI which is mostly due to prevention of deep percolation and evaporation from soil surface in the study area.

3.3 Agronomic parameters

The plant heights (cm) for the five reading after 30, 45, 60, 75 and 90 days showed that there was a significant difference between DI and SI (Table 5). In contrary, there were no significant differences between varieties of okra and interaction (system × varieties). For all the growth stages of the okra plants were taller under the DI as compared to that of the SI system (Fig. 5). The mean plant height after 90 days under DI and SI system was 49.51 and 33.37cm, respectively (Table 6), which conforms, to the results of [22]. Stem diameter (Table 7) after 30, 45, 60, 75 and 90 days from plant growing, showed no significant differences between DI, SI and between okra varieties well as the interaction (i.e. system× varieties) in the first and second reading of plant diameter. Whereas, significant differences were noted between drip and surface irrigation, the okra varieties and the interaction for the rest of the readings expect for the variety in the fourth one. The, DI significant increase can be attributed to the conserved soil moisture, seedling emergence, and improved plant growth which resulted in increased plant height and stem diameter. The mean plant diameter under DI after 90 days from plant growing was 0.81cm while under SI was 0.61cm as shown in Table 8. The increase stem diameter under DI was more than those under SI (Fig. 6) as indicated in results by [23] in the studies of vegetative growth.

Table 1: Mean monthly meteorological data and mean of reference crop evapotranspiration

Month	Mean temperature°C		Relative humidity %	*WS (m/h)	Sunshine (hrs.)	ET_o mm/day
	max	Min				
Nov	36.10	21.50	37	2.11	10.0	7.00
Dec	32.70	20.40	33	2.11	9.90	6.40
Jan	29.00	14.90	32	2.37	9.10	6.00
Feb	31.30	15.90	31	2.60	9.10	6.70
Mean	32.30	18.80	33.25	2.29	9.53	6.53

*wind speed at height at 2m.

Table 2: Okra water requirement

Month	Nov	Dec	Jan	Feb	Mean
ET_o mm/day	7.00	6.40	6.00	6.70	6.53
Kc	0.60	0.75	1.00	0.80	0.79
ET_c mm/day	4.20	4.80	6.00	5.40	5.10
ET_c mm/month	126	144	180	162	153

Table 3: The net crop water requirement (NCWR) for Okra

Month	ET_c mm/month	NCWR (mm/month)	NCWR m^3/ha/month
Nov	126	6.70	6.53
Dec	144	0.80	0.79
Feb	180	5.40	5.10
Feb	162	162	153
Total	153		

Table 4: Crop WUE of the Okra crop grown under different irrigation systems

Irrigation method	Yield kg	Total amount of water m^3	WUE kg/m^3
DI	17150	581.5	29.49
SI	11980	920.2	13.02

Table 5: Variance analysis for plant height (cm) of Okra varieties grown under different irrigation systems

Source	Df	Days from sowing				
		30	45	60	75	90
System	1	25.61**	36.26**	1675.61**	3866.43**	3126.64**
Block/system	2	07.50	10.22	108.85	339.41	0439.03
Varieties	2	0.83^{ns}	03.35^{ns}	14.87^{ns}	38.09^{ns}	35.05^{ns}
Varieties × system	2	0.79^{ns}	12.36^{ns}	55.16^{ns}	104.0^{ns}	119.59^{ns}
Error	4	0.52	11.78^{ns}	08.68	30.11	59.07
Total	11					
CV %		6.06	13.24	5.85	7.71	9.27

**: highly significant; ns: no significant.

Table 6: Plant height (cm) of Okra varieties grown under different irrigation systems

Treatment	Readings				
	1	2	3	4	5
DI	13.36	15.68	31.08	44.56	49.51
SI	10.43	10.22	19.26	24.55	33.37
V1	12.36	13.49	26.27	37.34	43.13
V2	11.87	12.75	24.46	31.36	40.37
V3	11.46	12.61	104.79	34.98	40.83
DI × V1	13.62	15.44	30.10	43.55	48.15
DI × V2	13.84	16.32	31.88	45.68	50.63
DI × V3	12.61	15.27	31.25	44.45	49.70
SI × V1	11.10	11.53	22.48	31.13	38.10
SI × V2	9.90	9.18	17.08	17.03	30.05
SI × V3	10.30	9.95	18.33	25.50	31.95
Overall mean	11.89	12.95	25.17	34.56	41.44
LSD* 5 % 4sys	1.02	3.36	4.16	7.75	10.86

*: LSD: least significant difference.

Table 7: Variance analysis for stem diameter (cm) of Okra varieties grown under different irrigation systems

Source	df			Days from sowing		
		30	45	60	75	90
System	1	0.006^{ns}	0.019^{ns}	0.139**	0.631*	0.371**
Block/system	2	0.013	0.019	0.031	0.099	0.084
Varieties	2	0.010^{ns}	0.020^{ns}	0.019*	0.011^{ns}	0.029*
Varieties × system	2	0.007^{ns}	0.032^{ns}	0.030*	0.365*	0.026*
Error	4	0.005	0.045	0.003	0.003	0.0002
CV%		41.21	36.84	3.44	4.69	1.03

**: High significant difference,*: Significant difference and ns: no significant difference

Table 8: Interaction of Stem diameter (cm) of okra varieties grown under different irrigation system

Treatment			Readings		
	1	2	3	4	5
DI	0.085	0.313	0.491	0.730	0.777
SI	0.092	0.263	0.383	0.501	0.602
V1	0.082	0.331	0.457	0.632	0.728
V2	0.088	0.251	0.398	0.586	0.644
V3	0.097	0.283	0.458	0.630	0.698
DI × V1	0.071	0.313	0.468	0.713	0.783
DI × V2	0.087	0.313	0.450	0.688	0.720
DI × V3	0.098	0.313	0.555	0.790	0.830
SI × V1	0.093	0.348	0.445	0.550	0.673
SI × V2	0.088	0.188	0.345	0.483	0.568
SI × V3	0.095	0.253	0.360	0.470	0.565
Overall mean	0.089	0.288	0.437	0.616	0.689
LSD 5 % 4sys	0.01	0.29	0.074	1.33	0.02

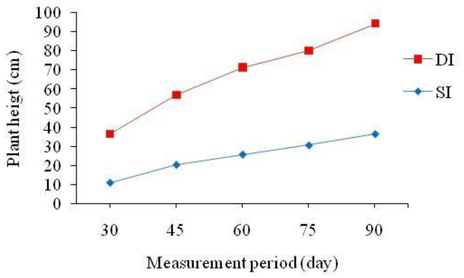

Fig. 5: Mean plant height (cm) of okra grown under DI and SI systems

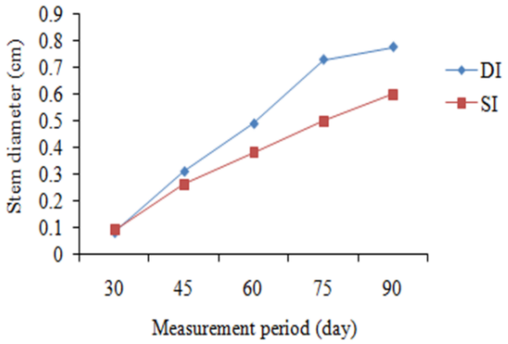

Fig. 6: Mean steam diameter (cm) of okra grown under DI and SI systems

3.4 Root length and weight

The results showed no significant difference between DI, SI, varieties of okra and interaction (varieties×system) for the length and weight (Table 9). This indicates that okra plant growth needs higher soil moisture. Fig 7 shows the length and weight of root zone was marginally under SI than DI system for the three varieties of okra. Different studies have shown significant relationship of different irrigation supply with root length, which triggers the accumulation of dry matter to the roots. Roots are in direct contact with soil and the first to be affected by the water logging. Thus growth is not faster under the SI, this system and result is in line with findings of [24], [22], [25].

3.5 Yield (kg/ha)

The results of yield for the nine picks, showed a significant difference in picks 1, 3, 5, 7, and 9 among the irrigation systems, the okra varieties and their interaction (system ×varieties). However, there were no significant differences in picks 2, 4, 6 and 8 for both irrigation systems and okra varieties and the interaction. This may be caused by variations of water requirements of okra are due to the nature of cultivars studied under the different methods. Referring to (Table 10) the increase in yield for all readings was more in the DI compared to the SI (Fig. 8). Similar results were obtained by [26]. [27] Stated that the highest fruit yield could be ensured with moderate intensity of irrigation. The increase in yield when using DI was 220.18, 1322.15 and 290.12% for V1, V2 and V3 respectively of that under SI. These results indicate that okra varieties (V1, V2 and V3) are suitable for improvement through selection in the study [28]. The overall mean yield for DI was 249.71 kg/ha, and that for SI was 155.65 kg ha^{-1}. Many studies reported on different crops irrigated by the drip and furrow irrigation methods in different parts of the world found that yield and WUE is higher with drip irrigation in comparison with furrow irrigation [29], [30], [31].

Table 9: Variance analysis for Root length (cm) and weight (g) of okra grown under two different irrigation systems

Treatments	Mean square	Observed F	Required F	
			5 %	1 %
Root length (cm)	85.336	0.137^{ns}	7.71	21.20
Root weight (g)	157.6875	0.619^{ns}	7.71	21.20

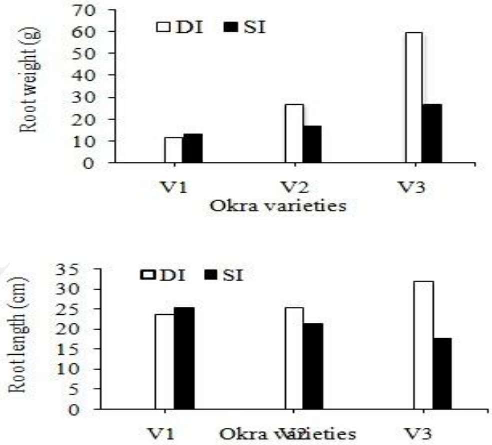

Fig. 7: Root length (cm) and weight (g) of Okra varieties grown under two different irrigation system

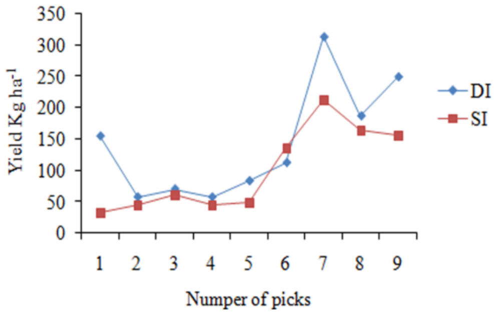

Fig. 8: Mean yield (kg/ha) of okra grown under DI and SI systems

Table 10: Yield (kg/ha) of interaction between okra varieties grown, DI and SI systems

Treatment	Number of picks								
	1	2	3	4	5	6	7	8	9
DI	155.41	58.06	70.99	58.06	83.83	112.86	313.48	187.51	249.71
SI	32.25	44.09	60.84	44.09	48.85	135.97	212.81	163.99	155.65
V1	84.363	65.5	63.61	65.50	74.91	103.08	300.41	186.22	163.28
V2	86.23	43.82	56.58	43.81	65.72	156.12	261.28	163.81	199.06
V3	110.89	43.91	77.54	43.92	58.41	114.06	227.75	177.22	245.68
DI × V1	128.57	61.00	86.31	61.00	85.31	112.66	341.13	192.16	127.75
DI × V2	161.13	65.69	43.00	65.69	89.69	89.69	370.06	170.00	274.38
DI × V3	176.53	47.50	83.65	47.50	76.50	136.25	229.25	200.38	347.00
SI × V1	40.156	70.00	40.91	70.00	64.50	93.50	259.69	180.28	198.81
SI × V2	11.33	21.94	70.16	21.94	41.75	222.56	152.50	157.63	123.75
SI × V3	45.25	40.32	71.44	40.32	40.31	91.25	226.25	154.06	144.38
Overall mean	93.828	51.08	65.91	51.08	66.34	124.37	163.15	175.75	202.68
LSD 5 %	64.24	31.83	87.66	285.5	57.68	168.50	109.80	98.94	360.95
CV%	24.2	22.05	5.99	41.50	30.8	56.9	14.76	19.92	20.7

1. CONCLUSION

Different methods of irrigation play a significant role in okra production. Thus, to maximum land utilization and water as well as production of okra calls for an effective irrigation system. The study revealed better plant growth, high water use efficiency and enhancement in the yield under drip irrigation as compared to the furrow irrigation method.

REFERENCES

1. J.C. Paul, J.N. Mishra, P.L. Pradhan, B. Panigrahi, (2013). Effect of drip and surface irrigation on yield, wateruse-efficiency and economics of capsicum (capsicum annum l.) Grown under mulch and non mulch conditions in eastern coastal india, European Journal of Sustainable Development, 2, 1, 99-10.8.
2. Kruger, E., Schmidt, G and Bruckner U, 1999. Scheduling strawberry irrigation based upon tensiometer measurement and climatic water balance model, Scientific Horticulture 87: 409-424.
3. Phocaides A, 2001. Pressurized Irrigation techniques Hand Book. Food and Agriculture organization (FAO), Rome, PP: 11-94.
4. Ahmed, A.A and Farah, S.M. 1991. The possibility of irrigation techniques in Sudan. Symposium on the Modern Irrigation Techniques in the Arab Countries, Morocco, A.O.A.D.
5. Ariyo, O. J., 1993. Genetic diversity in West African okra (*Abelmoschus caillei*) (A. Chev.) Stevels-Multivariate analysis of morphological and agronomic characteristics, Genet. Resour. Crop Evol, 40:25-32.
6. Oyelade, O.J., B.I.O. Ade-Omowaye and V.F. Adeomi, 2003. Influence of variety on protein, fat contents and some physical characteristics of okra seeds, J. Food Eng. 57:111-114.
7. Dilruba S., Hasanuzzaman, M., Karim R and Nahar K. 2009. Yield response of okra to different sowing time and application of growth hormones, J. Hortic. Sci. Ornamental Plants 1: 10-14.
8. Sorapong, B., 2012. Okra (*Abelmoschus esculentus* (L.) Moench) as a Valuable Vegetable of the World, Ratar. Povrt. 49: 105-112.
9. FAOSTAT, 2010. Food and Agriculture Organization (FAO), Statistical Data. 2010, FAO. *http://faostat.fao.org/site/339/default.aspx* accessed on 20/2/2013.
10. Sankara, R.G.H and T.Y. Reddy, 1995. Efficient use of irrigation Water. Kalyani Publishers, New Delhi. pp: 178-181.
11. Allen, R.G., Pereira, L.S., Raes, D and Smith, M, 1998. Crop evapotranspiration: Guidelines for computing crop water requirements. FAO irrigation and Drainage. Paper No. 56. *FAO Food and Agriculture Organization of the United Nations*, Rome, Italy, p. 300.
12. Doorenbos, G. W and A.H. Kassam, 1986. Yield Response to Water. FAO, Irrigation and Drainage paper No. 33.
13. Vermeiren, L and Gobling, G.A., 1980. Localized irrigation and Drainage Paper No. 36, Food and Agriculture Organization of the United Nations, Rome.
14. Nakayama, F.S and Backs, D.A, 1981. Emitter clogging effects on trickle irrigation uniformity. ASAE Trans, Paper No.81.2100.
15. Michael, A.M., 1978. Irrigation: Theory and Practice. 1st ed. VIKAS Puplishing house Ltd. New Delhi, India.
16. Ankeny, M.D., 1992. Methods and theory for unconfined infiltration measurements. *In*: Topp G.C. *et al.* (ed.): Advances in Measurement of Soil Physical Properties: Bringing Theory into Practice. SSSA Special Publication No. 30, SSSA, Madison, 123-141.
17. FAO, 2001. FAO Production Year book. Food and Agriculture organization of the United Nation 55: 121p.
18. James L.G., 1988. Principle of farm irrigation system design, John Wiley and sons 4th ed. Published by Ernest Ben Limited London.
19. Lubana, P.P.S and Narda, N.K, 2001. Modeling soil water dynamics under trickle emitters-a review, J. Agric. Eng. Res. 78, 217-232.
20. Segal, E., Ben-Gal, A., Shani, U, 2000. Water availability and yield response to high-frequency micro irrigation in sunflowers. In: Proceedings of the Sixth International Micro-Irrigation Congress, Int. Council Irr. Drainage. Cape Town, South Africa, October 22-27.
21. Ahmad, S.A., Mahmood A.J., Malik A. Karim and M.B. Kumbhar, 2003. Response of okra to water stress, Sarhad. J. Agri. 19:73-79.
22. Jayapiratha, V., M. Thushyanthy and S. Sivakumar, 2010. Performance evaluation of Okra (*Abelmoschus esculentus*) under drip Irrigation System, Asian J. Agric. Res, 4:139-147.
23. Pravukalyan P., Narendra N.S and Sanatan P, 2011. Evaluating partial root-zone irrigation and mulching in okra (Abelmoschus esculentus L.) under a sub-humid tropical climate, Journal of Agriculture and Rural Development in the Tropics and Subtropics, 112:169-175.
24. Rauf, S and H.A. Sadaqat, 2007. Effects of varied water regimes on root length, dry matter partitioning and endogenous plant growth regulators in sunflower (Helianthus annuus L.). J. Plant Interactions, 2: 41-51.
25. Panigrahi, P and N.N. Sahu, 2013. Evapotranspiration and yield of okra as affected by partial root-zone furrow irrigation, International Journal of Plant Production, 7:33-54.
26. Kamran B. S., Hakim A. S., Javaid A. R., Bhugro, M and Sakhawat, H. K, 2012. Effect of marginal quality water on Okra (*Abelmoschus*

Esculentus L.) Yield under drip irrigation system, Glo. Adv. Res. J. Eng. Technol. Innov. 1:103-112.

27. Verma, I.M and B.R. Batra, 2001. Effect of irrigation and nitrogen on growth and yield in okra. Changing scenario in the production systems of horticultural crops. *Proceedings of a National Seminar, Coimbatore, Tamil Nadu, India*, 28-30 August 2001. South-Indian-Horticulture, 49:386-388.
28. Panda, P.K and K.P. Singh, 1997. Genetic variability, heritability and genetic advance for pod yield and its contributing traits in okra hybrids, Madras Agric. J., 84:136-138.
29. Asgari, K., Najafi P and Solyimani A, 2007. Effects of treated wastewater on growth parameters of sunflower in the irrigation treatment conditions, Crop Research (Hisar) 33: 82-87.
30. Erdem T, 2006. Water-yield relationships of potato under different irrigation method and regimes, Scientia Agricola. 63: 226-231.
31. Gomez MÁO, 2006. Effect of three drip tape installation depths on water use efficiency and yield parameters in forage maize cultivation. Tecnica Pecuaria en Mexico. 44: 359-364.