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Effect of subsurface drip irrigation depth scheduling in summer Okra

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Abstract

A study was conducted on how different emitter rates with subsurface drip irrigation (SDI) affected the moisture distribution in clay loam soil of the coastal belt of Gujarat. The crop field experiments were conducted on summer okra (*Abelmoschus esculentus* L. Moench.) with 4 Lh-1 emitter rate (during 2013-14 and 2014-15) in sandy clay loam soil of KVK farm, JAU, Porbandar, Gujarat to assess the optimum irrigation regime and the depth of emission based on the yield performance. The experiment was executed with three irrigation regimes (0.6, 0.8 and 01.0 IW/ CPE) and different depth of lateral placements (0, 0.10, 0.15 and 0.20 m below the soil surface. The data of green pod yield with applied water was recorded during the experiment and subjected to split-plot design for analysis. It was found that significantly higher yield (15.46 Tha^{-1}) was obtained with 1.0 IW/ CPE level than other irrigation regimes. Pod yield in 15 cm depths of SDI laterals was found significantly higher than that under other lateral depths. The water use efficiency (25.01 kg/ ha-mm) was also higher with 0.15 m placement depth of lateral. The trend line of the production function of emission depth (yield – emitter depth) is fitted in the quadratic form (R^2=0.636). If the depth at which okra yield was found to be maximum taken as the correct depth for placement of drip tape in the soil that is 0.15 m. However, the optimum value of depth of emitter placement is computed using the production function of depth and it is found to be 0.119 m for maximum production.

Keywords okra yield, optimum emitter depth, production function, subsurface drip irrigation, water use efficiency

Introduction

Okra (*Abelmoschus esculentus* L. Moench.) is one of the economically important vegetable crops grown throughout the tropical and subtropical parts of the world either as the sole crop or as the intercrop. It is a warm-season vegetable crop and requires a long warm growing season. In India, it is grown in summer months and can do well in all kinds of soils, but sandy loam and clay-loam soils are better for its cultivation. Okra plays an important role in the human diet by supplying carbohydrates, protein, fats, minerals and vitamins that are usually deficient in the staple food [1].

India is the topmost country, producing 4.98 million tonnes of okra annually, which is around 73% of global okra production. The crop is grown year-round under varied soil and climatic conditions and despite it is considered as high water use crop, it has considerable drought resistance. The plant forms a deeply penetrating taproot with dense shallow feeder roots reaching out in all directions in the upper 0.45 m of soil. For greater yields,

Table 1. Depth wise average moisture content before irrigation in SDI

Emitter discharge rate, l h^{-1}	Radial distance (cm)	Moisture content % (d.b.) at various depths of emitter, cm				
		0	**0.10**	**0.15**	**0.20**	**Average**
2.0	10	18.98	19.09	19.75	19.78	19.40
	20	17.56	18.06	19.11	17.49	18.06
	30	16.99	17.69	18.19	17.11	17.50
	Avg.	**17.84**	**18.28**	**19.02**	**18.13**	**18.32**
4.0	10	20.11	20.65	21.23	21.18	20.79
	20	19.17	19.81	20.56	20.33	19.97
	30	16.81	18.50	19.22	18.07	18.15
	Avg.	**18.69**	**19.65**	**20.34**	**19.86**	**19.64**
8.0	10	22.52	23.78	23.77	23.78	23.46
	20	21.71	22.35	23.18	22.35	22.40
	30	18.36	19.36	20.61	19.36	19.42
	Avg.	**20.86**	**21.83**	**22.52**	**21.83**	**21.76**

suitable water supply and moderately moist soils are essential during the complete developing period. The influence of water deficit on yield in this span is more under surroundings of high temperature and low humidity. Frequency and emitter discharge rates determine the soil water availability and plant water uptake pattern and consequently the yield [2-3]. Illustrating the importance of matching the irrigation frequency to soil type, Ruskin [4] reported that a coarse-textured sandy soil required drip lines with higher flow rates and shorter irrigation cycles than clay soil. The higher irrigation water use efficiency and high yield were recorded with lesser water applications under the subsurface drip irrigation method [5]. Controlled irrigation is essential for high yields because the crop is sensitive to both over and under irrigation [6].

Among the available irrigation methods, subsurface drip irrigation (SDI) offers key advantages for meeting contemporary water and nutrient management efficiency standards, since it allows for accurate control of water supplied in small quantities directly to the root zone [7]. The SDI system has been used for irrigating many crops including the vegetables, horticultural and agronomic crops under different soil and climatic conditions [8-9]. SDI applies water below the soil surface, using buried drip which reduces evaporation, enhances water use efficiency, maintain congenial moisture regime in the root zone, and minimizes weed growth [10-11]. The biophysical advantages are the lower canopy humidity and fewer diseases.

With SDI, the choice of drip tape depth is influenced by crop, soil, climate characteristics, and anticipated cultural practices, but it generally ranges from 0.02 to 0.7 m. [12]. It is often in the range of 0.05 to 0.2 m for shallow-rooted horticultural crops. The depth of 0.15 m for lettuce would be appropriate on the sandy soils and the installation depth of SDI lateral should not be more than 20 cm for better crop establishment of the crop in Hanwood soil of Australia [13]. Dee The thoroughly located drip lines may need a higher amount of irrigation for germination/crop establishment. This process can consequence in off-site environmental outcomes [8], and it reduces the water-use efficiency. Deeper placement may restrict the availability of surface-applied nutrients and other chemicals. Germination of tomato (Lycopersicon esculentum Mill.) under SDI was better with drip line depths of 0.15 and 0.23 m than at 0.3 m on clay loam soil [14]. It can be assumed that shallow placement is especially important for the establishment if there is no supplementary source of surface irrigation. Shallow placement of drip tape is generally required also for satisfactory growth of shallow-rooted crops in sandy soils, which have limited capillary water movement, although this is not always the case, as Rubeiz et al., [15] found higher zucchini (*Cucurbita pepo*) yield at

Table 2. Effect of main plot treatment (irrigation regime) on yield of okra

Irrigation regime (IW/ CPE)	Year wise yield of okra (t/ha)		Pooled
	2013-14	2014-15	
0.6	12.74	12.99	12.87
0.8	12.8	14.23	13.51
1.0	15.61	16.04	15.83
S.Em.±	0.47	0.49	0.34
C.D. at 5 %	1.83	1.94	1.11
C.V. %	11.75	11.88	11.82

0.15 m depth than 0.04 m depth on a coarse loam soil. Thus, the optimum irrigation scheduling with appropriate emission rate play most important role in getting the better moisture distribution for root growth, yield and quality of the produce. Additionally, the depth of emission under SDI has greater influence on reduction of evaporation loss and simultaneously provide most suitable moisture regime to suit root zone of crop for better performance. Hence, a research was conducted to assess design parameters based on the performance of SDI in terms of proper emitter discharge rate, optimum irrigation regimes and depth of lateral placement that are most suitable for the summer okra crop. Moreover, information on water-yield relation (production function) and depth–a yield that is necessary in order to achieve optimal amounts of irrigation water and sustainable production of okra under subsurface drip irrigation was provided.

Methodology

A study was conducted to determine the moisture distribution pattern for the selection of optimum emitter rate with various depths of emission on a physical laboratory model of soil using soil-filled cube-shaped container. For this, two cuboids' shaped containers of plastic readily available in the market with a size of 75 cm × 37.5 cm × 75 cm were used. The lateral of the experiment was directly connected to the already running drip system to get the described pressure and mentioned discharge rates of 2, 4 and 8 l h -1and operated for the stipulated time of the experiment. For moisture distribution study of each treatment, twelve locations were selected around the dripper at one side; spacing at 10, 20 and 30 cm for moisture measurements located at perpendicular to plant row and lateral. Moisture content for each location was measured after redistribution or before irrigation (after 46 hours of irrigation) by gravimetric method a layer of 0, 10, 25 and 40 cm on one side considering that, there's symmetry around the emitter for both left and right-hand side. Emitter rate giving better moisture distribution coinciding with the root system of okra was selected for field experimentation.

Table 3. Effect of sub plot (depth of emission) on yield of okra

Depth of emission, m	Year wise yield of okra (t/ha)		Pooled
	2013-14	2014-15	
0.00	12.33	13.34	12.84
0.10	13.88	14.36	14.12
0.15	15.45	16.12	15.79
0.20	13.21	13.85	13.53
S.Em.±	0.33	0.39	0.25
C.D. at 5 %	0.97	1.16	0.73
C.V. %	7.15	8.13	7.68

The field experiments were conducted with 4 Lh^{-1} emitter rate (during 2013-14 and 2014-15) at the field of Krishi Vigyan Kendra, Junagadh Agricultural University, Khapat (Porbandar). The site is located at 21.40°N latitude and 69.37°E longitude with an altitude of 19 m from mean sea level. Field experiments were carried out under surface and subsurface drip irrigation system in order to optimize emission depth, the irrigation regimes for summer okra crop. The soil of this experimental site was clay loam with calcareous in nature. The upper layer of the soil was thin and shallow in-depth (0.65 to 0.75). The pH of the soil was ranging from 8.01 to 8.58. The water source was well with irrigation water having an EC value range between 2.54 to 4.6 dsm^{-1} and pH 8.19.

Table 4. Interaction effects of treatments on crop yield pooled data of two years

Irrigation regime (IW/ CPE)	Yield (t ha^{-1}) at depth of emission, m			
	0.0	0.10	0.15	0.20
0.6	12.32	13.33	14.22	12.10
0.8	13.37	14.70	15.87	12.96
1.0	14.34	15.06	18.27	16.50
Mean	13.34	14.36	16.12	13.85
S.Em.±	0.44			
C.D. at 5 %	1.27			

The experiment was executed with three irrigation regimes (0.6, 0.8 and 01.0 IW/ CPE) and different depth of lateral placements (0, 0.10, 0.15 and 0.20 m below the soil surface). Okra (variety GJOH-3) seeds were sown at 0.45 m × 0.15 m row- to- row and plant-to-plant spacing. One row of okra was kept on either side of lateral (0.225 m away from lateral). Thus, two rows of okra crop were irrigated with each lateral. Lateral depths and rows of okra crop have been illustrated in Figure 1. Plot size was kept 4.0 x 1.8 m for each of the treatments. PVC pipe of 75 mm × 4 kg/cm^2 was used as the main line and 63 mm × 4 kg/cm2 were used as a main and sub mainline. As a lateral drip line, 4.0 Lh^{-1}×37.5 cm × 16 mm diameter was used with a lateral cock of (16 mm) at the starting of the lateral line to control the irrigation water as per treatment.

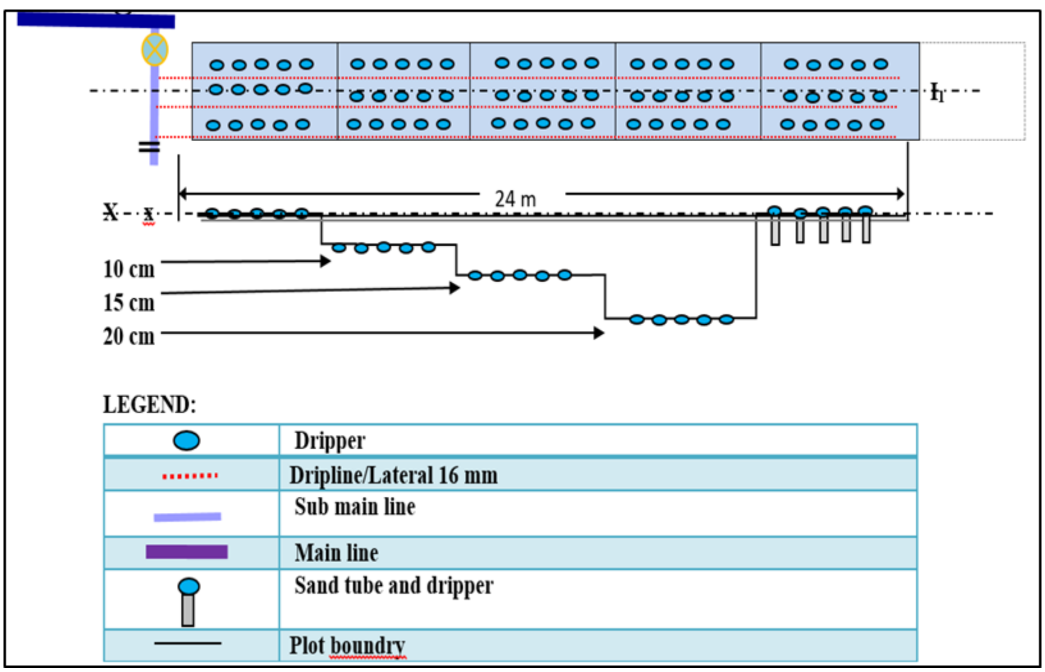

Figure 1. Schemetic layout of field experimental of subsurface drip irrigation system

The crop is sown after laying the dripline into the subsurface and ancillary observations of crop growth, yield and water use by the crop of experimental plots were recorded during experimentations. Tender pods of okra are its edible part these were ready for picking after generally 5-6 days after flowering. The pods were picked after every 2-3 days and pod-weights were documented. The total crop production was estimated by summing up all the recorded pod-weights. Split plot design was subjected to analyze the data of yield. Production function with applied water and relationship of depth of emission and yield were developed for the subsurface irrigation method to determine their optimum value.

Results and Discussion

Effect of discharge on moisture distribution pattern

The average moisture content before irrigation data for various emitter rates in horizontal grid paints and for surface and subsurface drip irrigation methods are presented in Table 1. Figure 2 shows the iso-moisture content lines for emitter discharge Q =2.0 L h^{-1}, Q = 4.0 L $h^{-1}$and Q = 8.0 L h^{-1}, and depth of emission D=0 and 15 cm. The moisture contents for emitter discharge 2.0, 4.0 and 8.0 L h^{-1} were found to be 18.32, 19.64 and 21.7 % respectively. This is 7.2 % and 18.8 % higher than that of the percent moisture contents for emitter discharge 2.0 L h^{-1} showing larger variation within the discharge rate. It is evident from Figure 2 that after redistribution (i e. moisture content after 46 hours of irrigation), the moisture content at emission point is higher and decreases as the distance from the emission point increases. The optimal moisture content for okra is 23.4 % (50 % deficient in available moisture content). At low emission rate (2.0 L h^{-1}), greater area was seen with a moisture content below 23.4 % indicating moisture stress condition. This prevailed at all the depth of lateral placements. The reverse was observed in the higher emission rate of 8.0 L h^{-1} at all the depths indicating oxygen diffusion to the crop roots. Hence, the emission rate of 4.0 L h^{-1} at

Table 5. Water use efficiency of okra under different placement depths of laterals

Irrigation regime (IW/ CPE)	Water use efficiency (kg/ha-mm) at depth of emission, m			
	0.0	**0.10**	**0.15**	**0.20**
0.6	21.62	23.40	24.96	21.24
0.8	17.60	19.35	20.89	17.06
1.0	15.10	15.86	19.24	17.38
Average	**18.11**	**19.54**	**21.70**	**18.56**

all the depths yielded moisture content congenial to plant growth. Patel and Rajput [16] also found a similar trend of water distribution in the soil around a buried dripper.

Performance in terms of yield

Effect of irrigation regime

The data of green pod of okra was collected treatment-replication wise for each of the plot and pickings. Total yield data plot-wise was subjected to Split plot design and the analysis for the main plot (irrigation regimes) are presented in Table: 2. During both the years and pooled data of the green pod yield of okra at a particular depth of emitter placement increase with an increase in irrigation regime was observed and the trend prevailed for all the depths of lateral placement. The effect of treatment was found to be significant and the highest pod yield (15.83 t ha^{-1}) was recorded with 1.0 IW/ CPE level of irrigation which is significantly higher than other levels of irrigation during the year 2013-14 and pooled of both the years. While during the year 2014-15 the trend was similar but the highest pod yield (16.04 t ha^{-1}) was recorded with 1.0 IW/ CPE level of irrigation which was at par with 0.8 IW/ CPE level and was significantly higher than 0.6 IW/ CPE level of irrigation. Higher the level of irrigation regime, more the amount of water applied which maintains more congenial moisture regime maintained within the root zone which may result in higher okra yield under higher irrigation regimes. The results corroborated the findings of [17-18].

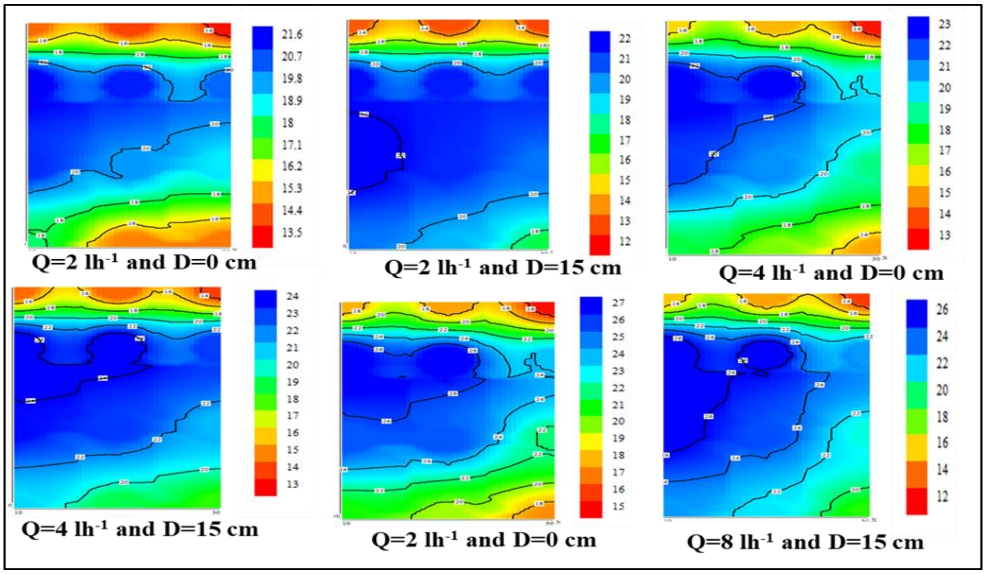

Figure 2. Iso-moisture content lines for various discharges and depth of emitter placements

Effect of depth of emission

The plot-wise data of total yield of the green pod are subjected to split-plot design and the analysis for subplot (depths of the emitter) are presented in Table 3. It is found from the table that at particular depth yield increased up to a certain level (0.15 m) and decreased after that. This trend prevailed at all the irrigation regimes. The yield at 0.15 m placement depths of SDI laterals was found significantly higher than that under 0.0 m (surface), 0.10 m and 0.20 m lateral depths for both the year and pooled analysis. The higher yield under SDI as compared to surface drip irrigation is in confirmation with Rubieiz et al., [15] and Camp [8] who found that yields of vegetables and field crops under SDI were equal to or greater than those for other methods of irrigation.

Combined effect

The plot-wise data of total yield of green pods are subjected to split-plot design the results of the combine effect of irrigation regimes and depth lateral on pod yield performance are presented in Table: 4. It is observed that the yield at 0. 15 m depth of SDI was found significantly higher than at 0.00, 0.10 m and 0.20 m lateral depth as stated by Singh and Rajput [19]. Moreover, significantly higher yield (16.50 Tha-1) was found with 1.0 IW/ CPE level than other irrigation regimes as obtained by Imtiyaz et al., [20]. In the interaction effect, highest yield was 18.27 Tha^{-1} was recorded with a combination of 1.0 IW /CPE irrigation regime and 0.15 m depth of lateral. The realization of higher yield under SDI as compared to surface drip irrigation (0.0 m) is in confirmation with [9, 21].

Water use efficiency

The water use efficiency of okra was calculated using mean yield and mean depths of water used during both the years of study and presented in Table 3. Water use efficiency kg/ ha-mm for various irigation regime and depth of emitter under SDI and depth-wise variation of WUE is illustrated in Figure: 3.

It may be observed from the table and figures that water use efficiency was higher with SDI. The maximum water use efficiency (21.7 kg/ ha-mm) was found with SDI 0.15 m placement depth of lateral. The behavior of water use efficiency with the placement depth of laterals for irrigation regime varies as the yield of okra. The reason is that the amount of water applied was not the same for all the treatments, the only yield was changed. The table indicates that water use efficiency decreases with an increase in irrigation regime for all the depths of laterals' placement. This may be due to reduced evaporation from the soil

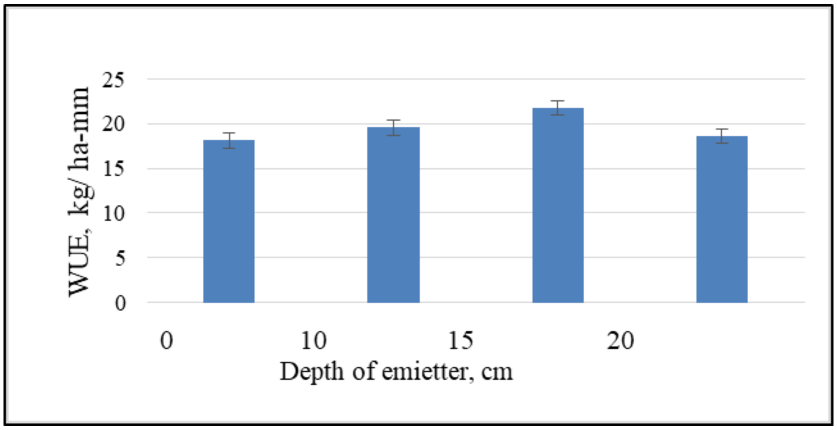

Figure 3. Water use efficiency kg/ ha-mm for various depth of emitter under SDI

surface and process of evapotranspiration is persuaded due to the water movement to the upward direction in the root zone, which enhancing water use efficiency, so more water is added to the root zone of the plant and minimized weeds growth around the crop [9, 17].

Water production function

The water production function for okra crop was obtained by plotting observed yield on the Y-axis and the applied water on the X-axis. Okra yield variation at different depths as a function of applied water (IW) illustrated in figure 4. The yield versus applied water is following a quadratic trend indicating that yield increase with applied water up to a certain level and decreases with increasing level of water applied. The goodness of fit was found to be 0.8971. Hence, to ensure the optimum yield of okra especially in summer seasons, a high water irrigation water application is needed, but where water is moderately scarce, medium irrigation treatment maybe serve as a supplement.

The water production function is expressed as in quadratic form (R2=0.897) in the following form

$$Y = -0.0008d2 + 7.4535d + 8946 \quad (1)$$

Where Y= Yield of crop kg /ha

d= Depth of water applied, mm.

Though the trend line looks like a linear relationship up to a certain level of water application. The extrapolated curve gets a downward trend at a high value of depth of water applied. The results corroborated with the findings of [22-27].

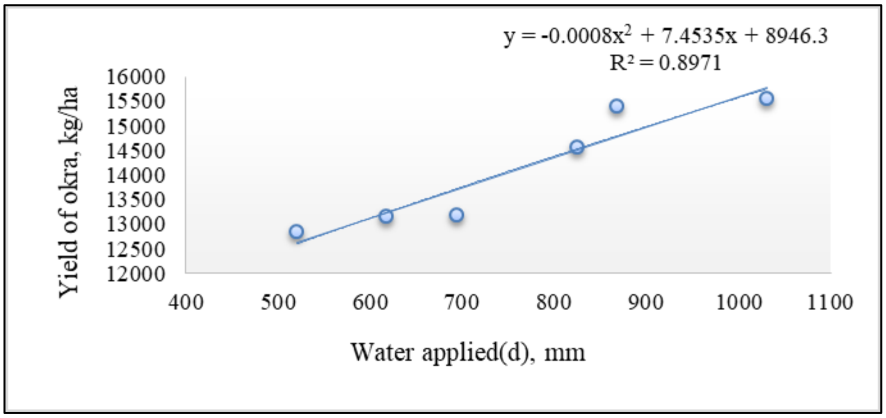

Figure 4. Water production function of okra under SDI

There are at least three possible explanations for the linear relationship between yield and crop water consumption: 1) CO_2 and water vapor share a common diffusive pathway at the leaf surface; consequently, stomata must be open and water transpired in order for crops to assimilate carbon from air surrounding leaves; 2) both water loss and photosynthesis are driven by absorption of light [28]. This may also happen due to the use of SDI has neither deep percolation nor evaporation losses whatever amount of water applied used for consumptive use of the plant.

Optimum depth of emission

Application of uniform and sufficient water to seed for good crop establishment is one of the most challenging issues of SDI. The establishment of the crop in SDI relies on unsaturated water movement from the buried source to seed. The process is therefore affected by the distance from the water source to seed, evaporative demand and hydraulic conductivity, which is dependent on soil texture, structure and antecedent water content. One of the most frequently debated features of the SDI system is the installation depth of the drip lateral.

SDI system is placed at the shallowest depth possible, consistent with avoiding damage from operations such as cultivation. However, if the lowest available dripper rate is greater than the soil intake rate, water surfacing can often result from irrigation. This can be reduced by burying the SDI system deeper into the soil [29]. The shallowest effective depth of burial can be found by keeping the drip tape at varying depths. Accordingly in the present study, drip tapes were placed at four depths of 0.0, 0.10, 0.15 and 0.20 m below the soil surface. For subsurface drip irrigation, the production of okra varies with the depth of emitter for a particular amount of water applied. Yield response with the depth of emitter placement is presented in figure 5.

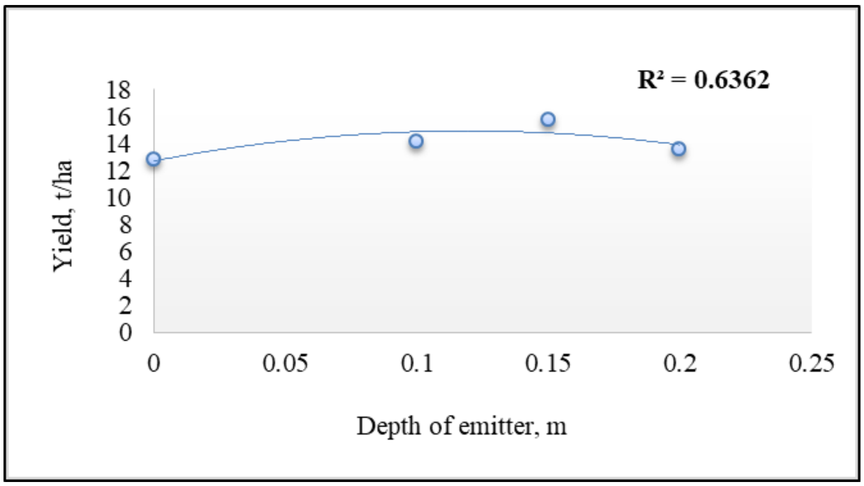

Figure 5. Effect of emission depth on okra production in SDI

It is revealed from the figure that yields increased with increasing depth of emission in SDI up to a certain point and after that yield decreases with emitter placement depth. This happened due to the initial stage establishment of the crop in deeper depth relies on unsaturated water movement from the buried source to seed or smaller roots so as to fulfill crop water demand. If the depth at which okra yield was found to be maximum taken as the correct depth for placement of drip tape in the soil i.e. 0.15 m. The trend line of production function of emission depth (yield –emitter depth) is fitted in quadratic form (R2=0.636) in following form.

$$Y = -156.8D2 + 37.334D + 12.71 \qquad (2)$$

Where Y= Yield of crop t/ha

D= Depth of emitter placement, m.

If the optimum value of depth is computed using this equation by first and second-order differentiation method, the optimum yield is obtained at D=0.119 m depth of emitter placement. The results match the findings of Schwankl and Prichard [14].

Conclusion

From the results of the experiment, it is concluded that in subsurface drip irrigation for okra crop under clay loam soil, the emitter discharge rate of 4.0 Lh-1, for maintaining the most suitable soil moisture regime. Subsurface placement of drip lateral gave better yield performance in okra crop than that in surface drip irrigation with a significantly higher yield (16.5 t ha-1) at 1.0 IW/ CPE level than other irrigation regimes.

A quadratic relationship was observed between the yield of okra crop and applied water in SDI. Crop perform better in term of yield and water use efficiency at 15.0 cm depth of SDI lateral than other lateral depths. However, the maximum yield was obtained at 11.9 cm depth of emitter placement if optimum value of depth determined from the quadratic relationship between yield and depth of emission.

References

[1] D. S. Kumar, D. E. Tony, A. P. Kumar, K. A. Kumar, D. B. S. Rao and R. Nadendla **(2013)**. An overview: *Abelmoschus esculentus* L (okra). Int. Res J. Pharm. App Sci.; **3:**129-132.

[2] D. A. Bucks, L. J. Erie, O. F. French, F. S. Nakayama and W.D. Pew **(1981)**. Subsurface trickle irrigation management with multiple cropping. Trans. of the ASAE, 24:1482-1489.

[3] A. M. El-Gindy and A. M. El-Araby **(1996)**. Vegetable crop response to surface and subsurface drip under calcareous soil. Evaporation and irrigation scheduling. *In Proc. Int. Conf. on Evapotranspiration and Irrigation Scheduling*. pp1021-1028

[4] R. Ruskin **(2005)**. Subsurface drip irrigation and yields. www.geoflow.com/agriculture

[5] D. E.Vories, P. L. Tacker, S. W. Lancaster and R. E. Glover **(2009)**. Subsurface drip irrigation of corn in the United States Mid-South. Agric. Water Manag., **96:** 912-916.

[6] A. R. Al-Harbi, A. M. AI-Orman and F.I. El-Adgham **(2008)**. Effect of drip irrigation levels and emitters depth on okra (*Abelmoschus esculentus*) growth. J. Applied. Sci., **8:** 2764-2769.

[7] M. E. Selim, A. A. Mosa and M. A. El-Ghamry **(2009)**. Evaluation of humic substances fertigation through surface and subsurface drip irrigation systems on potato grown under Egyptian sandy soil conditions. Agric. Water Manag., **96:** 1218-1222.

[8] C. R. Camp **(1998)**. Subsurface drip irrigation: a review. Transactions of the ASAE 41:1353-1367.

[9] R. M. Bajracharya and S. Sharma **(2005)**. Influence of drip irrigation method on performance and yields of cucumber and tomato. Kathmandu Uni. J. Sci., Engg. Tech., 1(1).

[10] F. S. Mohammad and A. I. Al-Amoud **(1994)**. Response of tomato crop to sub-irrigation with porous tubes in greenhouses. Al-Azhar J. Agric. Res., **19:**153-167.

[11] J. E. Ayers, J. C. Phene, A. R. Schoneman, B. Meso, F. Dale and J. Penland **(1995)**. Impact of bed location on the operation of subsurface drip irrigation systems. Proc. 5th Int. Micro Irrigation Congress, ASAE, pp168-174.

[12] C. R. Camp and F.R Lamm **(2003)**. Irrigation systems: subsurface drip. In *Encyclopedia Water Science*, pp560-564.

[13] B. P. Charlesworth and A. W. Muirhead **(2003)**. Crop establishment using subsurface drip irrigation: a comparison of point source and area sources. Irrig. Sci., **22:** 171-176.

[14] L. J. Sachwankel and T. L. Prichard **(1990)**. Clogging of buried drip irrigation systems. Calif. Agr., 44: 16-17.

[15] I. G. Rubeiz, N. F. Oebker and J. L.Stroehlein **(1989)**. Subsurface drip irrigation and urea phosphate fertigation for vegetables on calcareous soils. J. Plant Nutr., **12:** 1457-1465.

[16] N. Patel and T. B. S. Rajput **(2008)**. Dynamics and modeling of soil water under subsurface drip irrigated onion. Agric. Water Manag., **95:** 1335-1349.

[17] A. R. Al-Harbi, A. M. AI-Orman and F.I. El-Adgham **(2008)**. Effect of drip irrigation levels and emitters depth on okra (*Abelmoschus esculentus*) growth. J. Appl. Sci., **8:** 2764-2769.

[18] D. K. Singh, T. B. S. Rajput, D. K. Singh, H. S. Sikarwar, R. N. Sahoo and T. Ahmad, **(2006)**. Simulation of soil wetting pattern with subsurface drip irrigation from line source. Agric. Water Manag., **83:** 130-134.

[15] I. G. Rubeiz, N. F. Oebker and J. L.Stroehlein **(1989)**. Subsurface drip irrigation and urea phosphate fertigation for vegetables on calcareous soils. J. Plant Nutr, **12:**1457-1465.

[8] C.R. Camp (1998). Subsurface drip irrigation: a review. Trans. of the ASAE 41:1353-1367.

[19] D. K. Singh, and T. B. S. Rajput **(2007)**. Response of lateral placement depths of subsurface drip irrigation on okra (Abelmoschus esculentus). Int. J. Plant Prod., **1:** 73-84.

[20] M. Imtiyaz, N. P. Mgadla, B. Chepete and S. K. Manase **(2000)**. Response of six vegetable crops to irrigation schedules. Agric. Water Manag., **45:** 331-342.

[21] B. R. Batra, M. Inder and S. K. Arora **(2000)**. Effect of irrigation and nitrogen levels on dry matter production by okra (*Abelmoschus esculentus* L. Moench). Haryana J. Hort. Sci., **29:** 239-241.

[22] H. A. Alkaff and A.A. Hassan (2003). Effect of organic fertilizer and foliar application of power 4 on growth and yield of okra plants. Uni. Aden J. Nat. Appl. Sci., **7:** 25-35.

[23] X. P. Deng, L. Shan, H. Zhang and N. C. Turner **(2006)**. Improving agricultural water use efficiency in arid and semiarid areas of China. Agric. Water Manag., **80:** 23-40.

[24] F. N. Emuh, A. E. Ofuoku and E. Oyefia **(2006)**. Effect of intercropping okra (*Hibiscus esclentus*) with pumpkin (*Curcubita maxima* dutch ex lam) on some growth parameters and economic yield of maize (Zea mays) and maximization of land use in a fadama soil. Res. J. Biol. Sci., **1:** 50-54.

[25] S.M Sezen, A. Yazar and S. Eker **(2006)**. Effect of drip irrigation regimes on yield and quality of field grown bell pepper. Agric. Water Manag, **81:** 115-131.

[26] S. Konyeha and M. O. Alatise **(2013)**. Yield and water use of okra (*Abelmoschus esculentus* L. Moench) under water management strategies in akure, south western city of Nigeria. Int. J. Emer. Tech. Adv. Engg., 3: 8-12.

[27] A. Naveed, A. A. Khan and I. A. Khan **(2009)**. Generation mean analysis of water stress tolerance in okra (Abelmoschous esculentus L.). Pak. J. Bot., **41:** 195-205.

[28] R. S. Loomis and J. S. Amthor **(1999)**. Yield potential, plant assimilatory capacity, and metabolic efficiencies. Crop Sci., **39:** 1584-1596.

[29] M. A. Battam, B.G. Sutton and D. G. Boughton **(2003)**. Soil pits as a simple design aid for subsurface drip irrigation systems. Irrig. Sci., **22:** 135-141.