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National Academy of Agricultural Science (NAAS) Rating : 3. 03

# Hydraulic Performance of Drip Irrigation System and Fertigation Studies in Okra (*Abelmoschus esculentus* L. Moench)

**Rajanee Salunkhe[1], Deepika Bhamare[2] and Dipika Mavale[3]**

***ABSTRACT:*** *The experiment was carried out to check the hydraulic performance of drip irrigation and fertigation studies in okra under different drip irrigation schedules based on pan evaporation (40, 60 and 80% of PE) and levels of fertigation viz. 50, 75, 100 per cent recommended dose of fertilizers (NPK) through drip. A control treatment of conventional application of water and fertilizer (furrow irrigation at 1.0 IW/CPE with 60 mm depth and 100% RDF) was used for comparison. The designed flow rate of emitters used in the study was 4lh$^{-1}$. The maximum flow rate of emitter recorded was 3.46 lh$^{-1}$ whereas the minimum flow rate value was 3.33 lh$^{-1}$. The uniformity coefficient of drip system under all treatments were above 95% indicating its better design and performance. There were slight numerical variations in the values of uniformity coefficients showing higher in treatment $I_2F_1$ (96.99 %) and lower in treatment $I_2F_2$ (95.38%). As usual the field emission uniformity ($EU_f$) and absolute emission uniformity ($EU_a$)values were lower than the corresponding uniformity coefficients (Cu) The emitter flow rate variation ($q_{var}$) of 0.088 to 0.158 was observed in the present investigation reflects that the system was well performing and within the critical limit of flow variation.The average water requirement under drip irrigation scheduled at 0.4 PE, 0.6PE and 0.8PE and under surface irrigation are 394.7, 502.1, 609.4 and 660 mm. Water use efficiency and fertilizer use efficiency increases with decrease in the depth of irrigation water applied and fertilizer level, respectively. In order to have higher WUE and FUE drip irrigation system should be scheduled at alternate day with 0.4 PE depth of irrigation and fertilizer application of 100% RDF.For okra drip irrigation should be scheduled at 0.6 PE with 75% of RDF through water in five equal splits. Drip irrigation increases the okra fruit yield to the tune of 38.33%*

***Keywords:****Drip Irrigation, Fertigation, Uniformity Coefficient, field emission uniformity, absolute emission uniformity and water and fertilizer use efficiency.*

## INTRODUCTION

Scheduling of nutrients at right time, in right amount, in right manner at right place, is the crux of precision nutrient management. Micro irrigation, a technique that provides crops with water through a network of pipe lines at a high frequency but with a low volume of water (drips) applied directly to the root zone in a quantity that approaches consumptive use of the plants, can be combined with fertilizer application, to offer fertigation. Fertigation enables the farmer to meet the specific water and nutrient needs of the crops with great precision, thus minimizing losses of both precious water and nutrients. The direct delivery of fertilizers through drip irrigation demands the use of soluble fertilizers and pumping and injection systems for introducing the fertilizers directly into the irrigation system. Fertigation allows an accurate and uniform application of nutrients to the wetted area, where the active roots are concentrated. The nutrients are applied as per the crop need at different growth stages in split manner.

The problem of mobility of non-mobile nutrients is also addressed using fertigation. Planning the irrigation system and nutrient supply to the crops according to their physiological stage of development, and consideration of the soil and climate characteristics, result in high yields and high quality crops with minimum pollution.

[1] Ph.D. Scholar, Deptt. of IDE, Dr. PDKV, Akola. *E-mail: salunkhe7988@gmail.com*
[2] Ph.D. Scholar, Deptt. of SWCE, MPKV, Rahuri
[3] Ph.D. Scholar, Deptt. of SWCE, MPKV, Rahuri

**Table 1**
**Physico-chemical properties of soil at experimental site**

| Soil depth cm | Sand % | Silt % | Clay % | Textural class | Bulk density $gcm^{-3}$ | Water retention at, $cm^3cm^{-3}$ 0.33 bar | 15 bar | Saturated moisture content, $cm^3cm^{-3}$ | $K_s$, cm $day^{-1}$ | EC dS/m | pH |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-30 | 16 | 30 | 44 | Clayey | 1.36 | 0.35 | 0.18 | 0.40 | 22.10 | 4.09 | 8.7 |

"Okra" *(Abelmoschus esculentus* L.*)* is an herbaceous annual plant commonly known as 'Bhendi' or 'Ladies finger' belong to a family 'Malvaceae'. Okra is a native of Africa. It is grown throughout tropical and subtropical regions and also in the warmer part of the temperate region. Okra is grown throughout the world as an important vegetable crop covering an area of 6395 kg/ha. India is the second largest producer of vegetables next to china with 2.8% (6.2 Mha) of total cropped area under vegetables having annual production of 71.66 million tonnes. Amongst all vegetables cultivated in India, Okra is one of the most popular vegetable. In india okra occupies an area of about 3,70,000 ha with the productivity of 9594 kg $ha^{-1}$ (Anonymous, 2004).In Maharashtra area under okta cultivation is 9.3 thousand hactares with production of 120.5 thousand hactor tonnes. Okra is grown practically in all agro ecological zones mainly for its immature fruits which are eaten as cooked vegetables or added to soups (Anitha *et al*., 2001).

Increase in crop yield in drip irrigation was reported to be 10 to 70 per cent over conventional method depending upon the crop (Sivanappan and Padmakumari, 1980; Jadhav *et al.*, 1990; Singandhupe et al, 1998; Brahmanand and Singandhupe, 2001). Increase in yield over surface irrigation system was also observed as 100% in Cucumber (Robbins, 1977) and 76% in cauliflower (Kadale *et al.*, 1990).The varying degree of water saving in drip over surface irrigation depending upon the crop and season (Ghumare and Kadam, 1991; Pandit, 1996; Singandhupe *et al.* 1998) were reported as 60 per cent in cotton (Taley and Shekar, 2001), 40 per cent in Arecanut (PDC, 2003); 25 to 46 per cent in potato (Brahmanand and Singandhupe, 2001; Prabhakar and Hebber, 1996), 67 per cent in coconut (Varadan et al, 1991), 16 to 44 per cent in sugarcane (Selvaraj *et al.*, 1997), 50 to 70 per cent in other fruit crops (INCID, 1994) and 31 to 62 per cent in vegetables (INCID, 1994).

**Table 2**
**Details of treatments**

| *Sr. No.* | *Treatments* | *Specification* |
|---|---|---|
| 1. | $I_1F_1$ | Irrigation at 0.4 PE and 50% RDF. |
| 2. | $I_1F_2$ | Irrigation at 0.4 PE and 75% RDF. |
| 3. | $I_1F_3$ | Irrigation at 0.4 PE and 100% RDF. |
| 4. | $I_2F_1$ | Irrigation at 0.6 PE and 50% RDF. |
| 5. | $I_2F_2$ | Irrigation at 0.6 PE and 75% RDF. |
| 6. | $I_2F_3$ | Irrigation at 0.6 PE and 100% RDF. |
| 7. | $I_3F_1$ | Irrigation at 0.8 PE and 50% RDF. |
| 8. | $I_3F_2$ | Irrigation at 0.8 PE and 75% RDF. |
| 9. | $I_3F_3$ | Irrigation at 0.8 PE and 100% RDF. |
| 10. | Control | Conventional surface irrigation with 100% RDF through soil application |

In India more than 4.0 Mha of land have been brought under pressurized irrigation (sprinkler and micro irrigation). Most of the crops irrigated under micro irrigation are horticultural crops. In this paper effort has been madeto check the hydraulic performance of drip irrigation system and optimize the best irrigation and fertigation schedules for increasing productivity of Okraat Research Farm of All India Co-ordinated Research Project on water management, Marathwada Agricultural University, Parbhani.

## MATERIALS AND METHOD

### Experimental Site

The experiment was conducted during 2008-09 at research farm of All India Coordinated Research Project on Water Management, M.A.U., Parbhani. Geographically Parbhani is situated at an altitude of 409 m above the mean sea level in the central part of India and intersected by 76°47′ East longitude and 19°27′ North latitude.The topography of the experimental plot was fairly levelled having 0.2 per cent slope along the lateral (South to North) and 0.5 per cent along the submain (West to East). The soil of the surface layer (0-30 cm) was medium black clay in texture (440 g $kg^{-1}$), alkaline in reaction. To characterize the soil at experimental plot, physico-chemical analysis of soil sample from 0-30cm depth was carried out and presented in Table 1.

Experimental details:Field experiment was planned comprising of four irrigation schedules and

**Table 3**
**Schedule of fertilizer application according to crop growth stage (for 100% RDF)**

| | | | RDF (kg/ha) | | |
|---|---|---|---|---|---|
| *Sr. No.* | *Growth stage* | *DAS* | *N* | *P* | *K* |
| 1. | Initial growth stage | 15 | 20 | 5 | 10 |
| 2. | Vegetative stage | 30 | 20 | 10 | 10 |
| 3. | Flowering stage | 45 | 20 | 20 | 5 |
| 4. | Flowering and fruiting stage | 60 | 20 | 10 | 10 |
| 5. | Fruiting | 75 | 20 | 5 | 15 |
| | Total Application | | 100 | 50 | 50 |

three levels of fertilizers through fertigation under drip irrigation. The experimental design was split plot and randomized block design in which all treatments were replicated four times. The treatments consisted of three drip irrigation schedules and one control whereas there were three fertilizer levels with recommended dose as 100:50:50 kg ha$^{-1}$ of N: $P_2O_5$ and $K_2O$.The list of treatment combination was presented in Table 2

Performance of drip system:The performance of drip systems was evaluated by laying the laterals on levelled surface. The emitter discharge and pressure measurements were taken on selected laterals and emitters in each plot.

Emitter flow variation: The emitter flow rate variation ($q_{var}$) was determined using the following equation (Wu and Gitlin, 1974)

$$q_{\text{var}} = \left(1 - \frac{q_{\min}}{q_{\max}}\right) \qquad \ldots(1)$$

where, $q_{\min}$ is the minimum emitter flow rate and $q_{\max}$ is the maximum emitter flow rate.

## Field Emission Uniformity

The field emission uniformity (*EUf*) of each treatment was determined separately. Emission uniformity describes the uniformity of emission from all the emitter within an entire system and can be determined by using followingequation

$$EUf = 100\left(\frac{q_n}{q_a}\right) \qquad \ldots(2)$$

where, $q_n$ is the average of the lowest 1/4$^{th}$ of the field emitter discharge (lh$^{-1}$) and $q_a$ is the average of all the emitter discharges (lh$^{-1}$).

The absolute emission uniformity (*EUa*) can be determined by using the formula

$$EUa = \frac{1}{2} \times \left[\frac{Q\min}{Qavg} + \frac{Qavg}{Q\max}\right] \times 100 \qquad \ldots(3)$$

where,

*EUa* is absolute emission uniformity

$Q_{\min}$ is average of 1/4$^{th}$ of emitter discharges (lph).

$Q_{avg}$ is averag of emitter discharge (lph); and

$Q_{\max}$ -is average of 1/8$^{th}$ of emitter discharges (lph).

## Uniformity Coefficient

The coefficient of uniformity (*CU*) was used to estimate the emitter flow variation using the equation (Christiansen, 1941):

$$CU = 100\left[1 - \frac{\sum_{i=1}^{n}|q_i - q_a|}{\sum_{i=1}^{n} q_i}\right] \qquad \ldots(4)$$

where, $q_i$ is individual emitter flow rate, $q_a$ is mean emitter flow rate and $|q_i - q_a|$ is the absolute deviation from the mean.

## Manufactures Coefficient of Variation

The manufacturers' coefficient of variation, MCV, is used as a measure of variation in emitter flow rate and is mostly determined in the laboratory for new emitters. However, in order to know the performance the system and also to check emitter flow variation of some of the replaced emitters in the field during last three years of the system operation, the MCV was calculated using following equation.

$$M.C.V. = \frac{SDq}{qa} \qquad \ldots(5)$$

Where, *SDq* is the standard deviation of flow rates for the sample of emitter in lh$^{-1}$ and qa is the average flow rate for the sample of emitters in lh$^{-1}$.

Detail ofIrrigation scheduling andFertigation: The crop water requirement depends upon the factors related to plant, soil and climate. For irrigation planning the knowledge of crop water needs representing the response to the atmospheric evaporative demand is necessary Rajput and Patel (2002).

## Irrigation

The crop was irrigated by surface and drip method as per the treatments. For drip method, irrigation was scheduled at an alternate day. Initially cumulative pan evaporation (CPE) of two days was computed. For surface irrigated plots 6 cm depth of water was applied at 1.0 IW/CPE ratio through small furrows. Singh (1987) reported an increase in

**Table 4**
**Drip system performance indices under different treatments**

| *Treatment* | *Uniformity coefficient (Cu)%* | *Field Emission Uniformity ($EU_f$)%* | *Absolute Emission Uniformity ($EU_a$)%* | *Manufacturers coefficient of variation (M.C.V.)* | *Q avg (lph) (at 1 kg/cm²)* | *Q var* |
|---|---|---|---|---|---|---|
| $I_1F_1$ | 95.56 | 92.25 | 92.35 | 0.050 | 3.33 | 0.150 |
| $I_1F_2$ | 96.12 | 91.46 | 92.26 | 0.054 | 3.35 | 0.149 |
| $I_1F_3$ | 96.68 | 93.90 | 94.1 | 0.043 | 3.38 | 0.115 |
| $I_2F_1$ | 96.99 | 95.37 | 95.48 | 0.035 | 3.46 | 0.088 |
| $I_2F_2$ | 95.83 | 94.34 | 94.28 | 0.048 | 3.40 | 0.111 |
| $I_2F_3$ | 96.99 | 95.06 | 94.99 | 0.038 | 3.40 | 0.098 |
| $I_3F_1$ | 96.56 | 94.67 | 94.45 | 0.043 | 3.38 | 0.111 |
| $I_3F_2$ | 96.46 | 93.68 | 94.02 | 0.045 | 3.42 | 0.116 |
| $I_3F_3$ | 96.31 | 93.45 | 92.88 | 0.048 | 3.36 | 0.137 |
| Mean | 96.39 | 92.86 | 92.93 | 0.045 | 3.35 | 0.119 |

vegetative growth of okra with increase in irrigation amounts ranging from 40% to 100% of pan evaporation (PE).Under drip irrigation at 0.8 cumulative pan evaporation increase in sugarcane yield (9%) and water use efficiency (25.8%) as compared to surface flooding has also been reported (Malavia *et al.*, 2001).

(i) The quantity, of water required per plot in liters was computed by using the following equation:

$$Q = d \times L \times W \qquad \dots(6)$$

in which, $Q$ = Volume of water to be applied (lit); $L$ = Length of furrow (m); $W$ = Width of furrow (m) and $d$ = depth of water to be applied (mm).

(ii) The depth of irrigation is calculated by using following equation:

$$D = n \times CPE \qquad \dots(7)$$

in which, $D$ = Depth of irrigation; $n$ = compounding factor (representing crop coefficient and pan coefficient $Kp$ = 0.7) and $CPE$ = Cumulative pan evaporation of previous two days

(iii) Volume of water to be applied per plot in drip is calculated by using the eq$^n$.

$$V = D \times A_C \qquad \dots(8)$$

in which, $V$ = Volume of water applied (lit); $D$ = Depth of water to be applied (mm) and $A_C$ = Wetted Area.

(iv) Time of system operation was calculated with the help of following equation:

$$V = \frac{T}{q} \qquad \dots(9)$$

In which, $T$ = Operation time of system (min); $V$ = Volume of water applied (lit); and $q$ = Emitter discharge (lph).

### Fertigation

The sources of major nutrients NPK used in the experiment were water soluble fertilizers and applied through water using venturi applicator. The increase in the levels of fertilizers was found to improve the growth and yield. For Parbhani kranti variety of okra Singh and Singh (1999) reported increase in seed yield with increase in the fertilizer level upto 120 kg N/ha. A field experiment on yield response of okra to different level of fertigation conducted by Rajput and Patel (2002) in cv. Arka Anamika and observed that highest yield was obtained with fertigaion at 100% recommended fertilizer rate *i.e.* 120:20:60 NPK kg/ha.The schedule of fertilizer application for drip irrigated plots during crop growth period is presented in Table 3.

## RESULTS AND DISCUSSION

### Performance of Drip System

The hydraulic performance of drip system was evaluated during the investigation period. From each experimental plot, the laterals and emitters were selected for monitoring the discharge and pressure variations. Various drip system performance indices *viz.* emitter flow variation, field emission uniformity ($EU_f$), absolute emission uniformity ($EU_a$), coefficient of uniformity ($CU$), and coefficient of manufacturer's variation ($M.C.V.$) were determined to evaluate the system performance based on uniformity in distribution and emitter clogging. The data is presented in Table 4.

The designed flow rate of emitters used in the study was 4lh$^{-1}$. The maximum flow rate of emitter recorded was 3.46 lh$^{-1}$ whereas the minimum flow rate value was 3.33 lh$^{-1}$. The uniformity coefficient of drip system under all treatments were above 95%

indicating its better design and performance. There were slight numerical variations in the values of uniformity coefficients showing higher in treatment $I_2F_1$ (96.99%) and lower in treatment $I_2F_2$ (95.38%). As usual the field emission uniformity ($EU_f$) and absolute emission uniformity ($EU_a$)values were lower than the corresponding uniformity coefficients (Cu) The emitter flow rate variation ($q_{var}$) of 0.088 to 0.158 was observed in the present investigation reflects that the system was well performing and within the critical limit of flow variation. Normally for the new emitters under standard laboratory conditions (fixed pressure and temperature at 20°C) the manufacturer's coefficient of variation (MCV) of 5% for class A and 10% for class B is acceptable. The estimated MCV values under different treatments in the present investigation are in the acceptable range. There was no significant effect of treatments on the system performance indices.

### Water Requirement of Okra

The water requirement of okra under each treatment was estimated using the depth of irrigation applied during the crop growth period. Data presented in Table 5 reveals that the total depth of water applied at different irrigation schedules *viz.* 0.4 PE ($I_1$), 0.6 PE ($I_2$), 0.8 PE ($I_3$) through drip and at 1.0 IW/CPE through furrow irrigation ($I_4$) were 394.7, 502.1, 609.4 and 660 mm respectively. Data shown in Table 5 indicate that all the treatments under $I_1$ irrigation schedule of drip irrigation showed highest water use efficiency (WUE) than $I_2$ and $I_3$. The higher WUE under $I_1$ can be due to low depth of irrigation water applied on the other hand increase in yield of okra resulted in higher WUE even if same quantity of water was applied as under $I_1F_2$ and $I_1F_3$. The highest WUE was under $I_1F_3$ (33.71 kg/ha-mm) treatment and the lowest was under control treatment (13.31 kg/ha-mm) where water was applied conventionally through furrow method. On the other hand, the increase in fertigation level improved the WUE only under $I_1$ irrigation schedule whereas under $I_2$ and $I_3$ irrigation schedules the higher fertigation level ($F_2$-75 and $F_3$-100% RDF) did not increase the yield to the extent which could improve the WUE. Data presented in Table 5 show that the highest fertilizer use efficiency (FUE) was in $I_1F_3$. Generally the increase in fertilizer use decreases the FUE. However under $I_1$ irrigation schedule the increase in fertilizer level significantly increased the total fruit yield of okra resulting in higher FUE. This was not the case under $I_2$ and $I_3$ irrigation schedule where with increase in fertilizer level decreased the FUE. The lowest FUE was observed under control treatment where fertilizers were applied conventionally by band placement.

**Table 5**
**Water and Fertilizer use efficiency of okra under different treatments**

| *Treatments* | *Yield of okra (t/ha)* | *Irrigation water applied (mm)* | *Water use efficiency (kg/ha-mm)* | *Fertilizer used (kg) (t/ha-kg)* | *Fertilizer use efficiency* |
|---|---|---|---|---|---|
| $I_1F_1$ | 9.30 | 394.72 | 22.17 | 100 | 92.99 |
| $I_1F_2$ | 12.77 | 394.72 | 30.44 | 100 | 127.72 |
| $I_1F_3$ | 14.14 | 394.72 | 33.71 | 100 | 141.41 |
| $I_2F_1$ | 13.82 | 502.08 | 26.23 | 150 | 92.14 |
| $I_2F_2$ | 14.04 | 502.08 | 26.65 | 150 | 93.63 |
| $I_2F_3$ | 13.36 | 502.08 | 25.35 | 150 | 89.04 |
| $I_3F_1$ | 13.22 | 609.44 | 20.85 | 200 | 66.12 |
| $I_3F_2$ | 14.87 | 609.44 | 23.45 | 200 | 74.35 |
| $I_3F_3$ | 14.39 | 609.44 | 22.69 | 200 | 71.96 |
| $I_4$ | 9.12 | 660.00 | 13.31 | 200 | 45.59 |

## CONCLUSION

The hydraulic performance of drip system was evaluated during the investigation period. The average uniformity coefficient, field emission uniformity, absolute emission uniformity and manufacturing co-efficient of variation were 96.39,92.86,92.93 and 0.045 respectively. The performance of system was within the acceptable limit. The drip irrigated okra show better growth compared to surface irrigation.For okra drip irrigation should be scheduled at 0.6 PE with 75% of RDF through water in five equal splits. Drip irrigation increases the okra fruit yield to the tune of 38.33%. The average water requirement under drip irrigation scheduled at 0.4 PE, 0.6PE and 0.8PE and under surface irrigation are 394.7, 502.1, 609.4 and 660 mm. Water use efficiency and fertilizer use efficiency increases with decrease in the depth of irrigation water applied and fertilizer level, respectively. In order to have higher WUE and FUE drip irrigation system should be scheduled at alternate day with 0.4 PE depth of irrigation and fertilizer application of 100% RDF.

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