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Original Research Article

Performance Evaluation of Drip System of Irrigation for Brinjal Crop

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A B S T R A C T

Drip system of irrigation provides enhanced water use efficiency and water application efficiency up to 90% whereas it is about 70% for sprinklers and 45% for flood method of irrigation. In this method as water is supplied directly to crop root zone through drippers, water losses in distribution and conveyance are far lower than those under flood irrigation. A case study was conducted regarding performance evaluation of drip irrigation system used for growing brinjal in the village Shivpur, district Mungeli in Chhattisgarh. The study was conducted in 50 ha area of farmer's field, irrigated with drip irrigation. The emitter discharge was found to be 0.85 lph. The number of emitters installed in brinjal field in 1 ha area was 90. In all 5 pumps were supplying water to different crops, out of which 4 were electric operated, each of 3 hp whereas one pump of 5 hp was operated with solar power. On an average the uniformity coefficient of surface and sub-surface drip irrigation system for brinjal was found to be 83.6% and 73.2% respectively. The plugged emitters in sub surface drip irrigation were the main causes of lower uniformity coefficient.

Introduction

Drip system of irrigation has been found to be one of the most efficient irrigation systems for the production of vegetables as well as orchard crops. In this system water is applied nearly at the root zone of the plant at frequent intervals for a long period of time. Drip irrigation can potentially provide high application efficiency and achieve high application uniformity. Both are important in producing uniformly high crop yields and preserving water quality. Subsurface drip irrigation offers advantages of less

evaporation loss and less interference with intercultural operations. However as most system components are located below the soil tillage zone it is difficult to monitor system operations.

In Chhattisgarh region about 30% of net cropped area was under irrigation in 2011-12 whereas the average national irrigation was about 40%. The irrigation is characterized by a high order variability ranging from 0% in Dantewada to 82% in Raipur.

In the existing scheme of micro-irrigation running under the state, the brief about the micro-irrigation system viz. drip and sprinkler systems of irrigation at the fields of beneficiaries since 2005-06 to 2012-13 are 11693 ha and 146317 ha through drip and sprinkler respectively (Das *et al.*, 2016).

Brinjal is a warm crop. A daily mean temperature of 13-21^{0}C is most favourable for its successful production. The soil pH should not be higher than 5.5 to 6.0 for its better growth and development. Timely irrigation is quite essential for good growth, flowering, fruit setting and development of fruits. Higher yields may be obtained at optimum moisture level and soil fertility conditions. In plains, irrigation should be applied every 3rd to 4th day during hot weather and every 7 to 12 days during winter. Recommended dose of NPK is 200:150:100 kg/ha (nhb.gov.in/pdf/vegetable/brinjal/bri011.pdf).

To determine if water and chemicals are applied uniformly, it is necessary to evaluate emitter discharge uniformity and system performance. The objective of the study was to evaluate the performance of drip irrigation system on brinjal crop on the basis of emitter flow rate variations, field emission uniformity, design emission uniformity and irrigation efficiency.

Materials and Methods

Experimental site and plant material

The experiment was conducted in a farmer's field, located at Shivpur village, 8 km away from campus of BRSM CAET & RS, Mungeli during the period -10th September 2015 to 2nd January 2016. The study area was characterized by warm summer and received normal rainfall of 1007.8 mm from SW monsoon and 80.1 mm from NE monsoon. The soil of the experimental site was black cotton soil. The site was ploughed and harrowed and then beds were prepared at a spacing of 1.3 m. One month old planting material of brinjal (variety VNR-212), was transplanted in the field on 31 October 2015 with a row to row spacing of 1.2 m in an area of 0.8 ha under drip whereas the gross cultivated area was 1 ha.

Drip system description

Drip system was installed in the farmer's field in 0.8 ha area for growing brinjal crop. The specification of drip irrigation system is given in Table 1.

The water source of the area was deep tube well operated by 3 hp submersible electric pump set, with a discharge in the range of 8 lps. The drip irrigation system was installed with submersible pump, non-return valve, water meter, filters, fertilization equipment and flow control, air pressure release valves, on-and-off valves and pressure gauge. The mains and sub-mains were laid underground, at a depth of 45 cm to avoid damage due to vehicles and equipments. The main pipe was 75 mm and sub-main pipe was 63 mm in diameter. There were 45 lateral lines 15 mm in each sub-main pipe line. Thus in all 135 laterals were used to irrigate 0.8 ha land. Line source emitters, 100 per lateral with spacing of 0.45 m were used.

Measurement of emitter discharge

The discharge of emitters was measured in different laterals at 10 different locations including nearest, middle and farthest points from the sub-mains. The measurement of discharge of emitters was undertaken by measuring the volumetric flow of water for an hour time and the discharge was expressed in litres per hour (lph).

Estimating uniformity of drip irrigation

The emission uniformity (EU) on the system is the most important parameter to know the system performance. Emission uniformity can be evaluated by direct measurement of emitter flow rate. The water application uniformity of emitters is influenced by the operating pressure, emitter spacing, land slope, size of pipeline, emitter discharge rate and emitter discharge variability.

The emitter flow variation that is determined from the emitter flow profile of the lateral line considers only the variation caused hydraulically and assumes that there is no emitter flow variation from the manufacturer. In fact, for any emitter in the lateral line, there will be manufacturer's variation that depends on the manufacturer's quality control in production.

Manufacturer's Variation

The manufacturer's variation is actually caused by the non-uniform production from the manufacturer. If there is no manufacturer's variation, the emitter flow should be identical for each pressure.

$$C_v = \frac{s}{q_{av}} \quad (1)$$

where, C_v is the manufacturer's coefficient of variation of emitter flows is the standard deviation of emitter flow and q_{av} is the mean emitter flow.

Emitter Flow Variation Caused by Manufacturer's Variation

$$q_{var} = \frac{q_{max} - q_{min}}{q_{max}} \quad (2)$$

where, q_{max} is maximum emitter flow, q_{min} is minimum emitter flow and q_{var} is the emitter flow variation.

It can also be expressed by the manufacturer's coefficient of variation as follows:

$$q_{var} = \frac{1 - 2C_v}{1 + 2C_v} \quad (3)$$

Emitter flow variation contributes to the total emission uniformity (EU) of an irrigation system.

Field emission uniformity

$$EU_f = \frac{q_{min}}{q_{av}} \times 100 \quad (4)$$

Where, q_{min} is minimum emitter discharge and q_{av} is average emitter discharge.

Design emission uniformity

The design emission uniformity or uniformity coefficient is a measurable index of degree of uniformity for any size emitter operating under given conditions.

Karmeli and Keller (1975) were the first to define an empirical design emission uniformity percentage EU for evaluation of the performance of drip irrigation system. Based on it the following equation is commonly used to estimate the design emission uniformity in drip irrigation systems.

$$EU = 100 \times \left[1.0 - \frac{1.27 \, C_v}{\sqrt{n}}\right] \times \frac{q_{min}}{q_{av}} \quad (5)$$

where, EU is design emission uniformity (%), n is the number of emitters per plant, C_v is manufacturer's coefficient of variation, q_{min} is minimum emitter discharge rate(lph) and q_{av} is average emitter discharge rate(lph).

The commonly recommended ranges in design emission uniformity of line sources emitter on annual or perennial crops are:

a) Land slope less than 2%= 80% to 90%
b) Land slope greater than 2%= 75% to 85%

The flow rate variations of emitters in laterals with respect to its distances from sub-main pipe i.e. in head, middle and tail end reaches were studied and the results were tabulated and analysed.

Irrigation efficiency

The overall application efficiency of drip irrigation (E_a) is defined by Vermeiren and Gobling (1980)as follows:

$$E_a = K_s \times EU \quad (6)$$

where, K_s is the ratio between water stored and that diverted from the field. Table 2 shows values of K_s for different soil types and EU is the emission uniformity of drip irrigation system.

Results and Discussion

Emitter discharges

The results of the study of emitters flow rate in different reaches of laterals indicated that the overall average flow rate of emitters was approximately 1.0 lph. The average flow rate in head reaches was found to be 1.112 lph which was highest (Table 3). The average

flow rate in middle reaches was found to be 0.97 lph (Table 4). On the contrary, the average flow rate of emitters located at tail end reaches was found to be 0.9175 lph (Table 5) which was lowest.

Emitter flow rate variation

Low the emitter flow rate variation better is the performance of the drip irrigation system. The value of emitter flow rate variation calculated was **0.225** which was quite satisfactory for smooth and continuous operation of the system.

Manufacturer's coefficient of variation

The manufacturer's coefficient of variation for the emitter material was obtained as **0.09**. This value of C_v is accepted as good for efficient operation of the system. The recommended ranges for C_v in line source emitters are given in Table 6.

Field emission uniformity

The field emission uniformity was calculated to be 90.9%. This shows better water application uniformity by the emitters in the field. It mainly depends upon the system operating pressure, emitter physical properties and their blocking potential.

Design emission uniformity

The uniformity coefficient as calculated by Eq 5 and Table 7 was found to be **80.5%**. This value represents efficient drip system of irrigation. The water application uniformity of emitters is influenced by the operating pressure, emitter spacing, land slope, size of the pipeline, emitter discharge rate and emitter discharge variability. The value of EU can be improved by reducing the difference between q_{min} and q_{av} or by using an emitter with a lower C_v.

Table.1 Specification of DIS for brinjal crop under study

Crop	Brinjal
Emitter type	inline emitter
Row to row distance	1.3m
Plant spacing	0.6m
Emitter spacing	0.4m
No. of laterals per row	1
Avg. emitter discharge	1 lph
Evaporation equivalent	5 mm/day
Irrigation cycle	1
Duration of one operation	2 h
Gross area	1 ha
Net area	0.8 ha
Water source	Tubewell
Water requirement	700 mm/day
Length of lateral	45 m

Table.2 Water storage efficiency and types of soil

Types of soil	Water storage efficiency (K_s)
Clay	100
Mixed silt, clay and loamy	95
Loamy	90
Sandy	87

Table.3 Emitters in laterals close to submain

S.No.	Emitter No.	Discharge (lph)
1	S1	1.162
2	S2	1.125
3	S3	1.05
Average (S1-S3)		**1.112**

Table.4 Emitters in laterals in middle portion

S.No.	Emitter No.	Discharge (lph)
1	S4	0.975
2	S5	0.96
3	S6	0.975
Average (S4-S5)		**0.970**

Table.5 Emitters in lateral in tail end

S.No.	Emitter No.	Discharge(lph)
1	S7	0.950
2	S8	0.920
3	S9	0.900
4	S10	0.900
Average (S7-S10)		0.9175
Overall Average (S1-S10)		$q_{av} = 1.0$

Table.6 Recommended values of Cv

S.No.	Value of C_v	Interpretation
1	Less than 0.10	Good
2	0.10 - 0.20	Average
3	More than 0.2	Marginal to unacceptable

Source: A.M. Michael

Table.7 Uniformity coefficient

S.No.	Emitter No.	Discharge (lph)	Deviation
1	S1	0.95	0.04
2	S2	0.9	0.09
3	S3	0.92	0.07
4	S4	0.975	0.075
5	S5	0.96	0.03
6	S6	0.975	0.015
7	S7	0.9	0.09
8	S8	1.125	0.135
9	S9	1.162	0.172
10	S10	1.05	0.06
Mean		**0.9917**	**0.717**

Irrigation efficiency

As the soil of the study plot was clay loam type, so the value of K_s was assumed to be 95. Thus, the irrigation efficiency was calculated as 76.5%.

In conclusions, the average flow rates of emitters were 1.112 lph, 0.97 lph and 0.9175 lph at the head end, middle and tail end respectively. The flow rate was higher than the overall discharge by 11.2% at head end, less than the overall discharge by 3% and 8.25% at the middle and tail end respectively which were well within the prescribed limit of 15%. The value of emitter flow rate variation calculated was 0.225 which was quite satisfactory for smooth and continuous

operation of the system. The manufacturer's coefficient of variation for the emitter material was obtained as0.09 which shows that the construction materials and design of emitters are good. Field emission uniformity of90.9% shows better water application uniformity by the emitters in the field. The design emission uniformity as expressed by formula given by Karmelli and Keller was estimated as 80.5% which was due to the ageing of pipelines resulting in clogging of pipes as well as emitters. The irrigation efficiency was found to be 76.5%. Irrigation efficiency in this case was less because of less maintenance of the drip system.

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