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Modeling Deep Percolation for Estimation of Water Use Efficiency of Vegetable Crops under Furrow Irrigation Practices

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ABSTRACT

Agriculture is the linchpin of Indian economy. Irrigated agriculture is a vital development tool for achieving the Millennium Development Goal. In agriculture evapotranspiration, seepage and deep percolation are the outflow parameters. Deep percolation (DP) among the outflow parameters plays a dominant role in lowering the water use efficiency of the crops in irrigated agriculture. Irrigation with the concept of management allowable depletion (MAD) level is considered as a better water management practice. However, this practice is rarely followed at field level due to ignorance of the end users. To estimate the deep percolation loss precisely, this study was carried out in the Instructional Farm of Orissa University of Agriculture and Technology, Bhubaneswar, Odisha during summer (Feb. 2017 to May 2017) at different MAD levels under furrow irrigation. From the experimental study, it was observed that sum total deep percolation at higher MAD level is less than that of lower MAD level. Mathematical model was developed for different MAD levels under furrow irrigation.

Key words: *Water Use Efficiency, Management Allowable Depletion, Furrow irrigation, Deep percolation*

INTRODUCTION

Irrigated Agriculture plays a major role in the livelihood of nations all over the world and Odisha is no exception. Irrigation is the largest consumer of water compared to the other sectors, but the share of water allocated to irrigation is likely to decreased by 10-15% in the near future due to shrinking water resources. In arid and semi-arid regions, water scarcity is the main yield limiting factor where it is difficult to apply full crop water requirements to sustain maximal growth and yield. Therefore, it is very important to determine how to maintain optimum crop yields under water deficit situations and also need for efficient water management practices for water use efficiency in crop production. A great reduction in seepage, percolation and evaporation allows for a greater WUE.

Increased surface evaporation, high rate of transpiration and deep percolation are associated with high frequency irrigation. Report reveals that deep percolation accounts for the major loss of water from the crop field.

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Direct measurement of DP is difficult under field conditions. Although lysimeters can be used to accurately measure DP under quasi-field conditions, they cannot be widely applied because of the high establishment and running cost. To estimate the deep percolation component of water loss precisely at the expense of least effort and funds, the concept of developing an empirical model based on lysimetric approach appears to be quite imperative at this stage.

MATERIAL AND METHODS

Study Area

The focused study was carried out under furrow irrigation at Instructional Farm of Orissa University of Agriculture and Technology, Bhubaneswar, Odisha during summer (Feb 2017 to May 2017). Mean annual rainfall at the site is 1450 mm, out of which eighty percent is received during the monsoon season from June to October. Average precipitation in winter (November to February) season is 23 mm. The summer months from March to May are very hot and humid, and temperatures often rise above 40°C in the month of May. The relief is almost flat.

Lysimetric installation

A digital weighing type lysimeter set up surrounded by the field was installed in the field to conduct the field experiments. It was installed in the open field to measure the deep percolation avoiding boundary effects due to metallic boundaries of lysimeter. There was no horizontal seepage and the water table had not affected the water balance due to the metallic boundaries. Drainage port provided at the bottom side of lysimeter allows the percolated water to drain in the buckets placed below the drainage ports. An observation trench was provided besides the lysimeter (in which measuring buckets are placed) to monitor the drainage water. Drainage from the drainage port of the lysimeter was taken as actual or observed value of deep percolation.

Fig. 1: Installation of Lysimeter in the experimental field

Cultural practices

The whole experimental plot was ploughed twice, i.e. both the first ploughing and second ploughing by power tillage and the soil was pulverized well. The land was uniformly leveled. Peripheral bunds were constructed for each sub plot of 80 square m. There were 12 number of sub plots in total as per the experimental design. There were four main plots which are based on different MAD levels (20%, 30%, 40% and 50% MAD level). Each main plot was sub divided into three sub plots based on the no of replication. For furrow irrigation plots, the length of furrow was 8 m. The width and depth of furrow was 25 cm and 8cm, respectively. Hybrid okra seeds of BSS-893 variety were chosen for cultivation.

Fig. 2: Sowing of hybrid okra seed

RESULTS AND DISCUSSION

Irrigation Scheduling

The irrigation requirement of the controlled plot with furrow irrigation was found to be in the range of 770 mm at 50 percent MAD level to 1050 at 20 percent MAD level. Irrigation requirement at 20 percent MAD level was observed to be higher than other irrigation levels because more irrigation water is required by the plant at this level due to more frequent irrigation application to the crop.

The sum total water requirement of the okra crop at different irrigation levels under furrow irrigation method was computed as the sum of the depth of irrigation water applied, effective rainfall, contribution from ground water through capillary rise and contribution from existing soil moisture. In the experimental site, effective seasonal rainfall during the crop growth period was only 72.3 mm out of four rainfall events. However, the contribution from ground water through capillary rise is assumed to be negligible in the present study. Irrespective with number of replication, average water requirement for the crop with furrow irrigation was found to be 807.3 mm, 740.8 mm, 695.3 mm and 617.3 mm at 20, 30, 40 and 50% MAD level, respectively.

Deep percolation analysis

Fig. 3 shows irrigation application, rainfall occurrences, and DP losses from the lysimeter during the crop growth season. Each time the depth of irrigation was to bring the soil moisture content to field capacity. Application of irrigation water was done by considering average root zone depth with the age of the crop. In furrow irrigation, water was applied at suitable intervals to maintain the designed MAD levels according to the root zone depth of the crop. In each replication, at 20 percent MAD level deep percolation is the lowest than other MAD levels but total deep percolation was observed to be the highest at 20 percent MAD level as compared to all the MAD levels which was mainly due to frequent application of irrigation water.

Total deep percolation rate was the highest at 20 percent MAD level at 60 cm depth of root zone due to the frequent application of irrigation water. It was lowest at 50 percent MAD level for 30 cm root zone depth. The number of irrigation events during the crop season was the highest at 20 percent MAD level while it was the lowest at 50 percent MAD level. Further, the total depth of water application was the lowest at 50 percent MAD level and highest at 20 percent MAD level in furrow irrigation method.

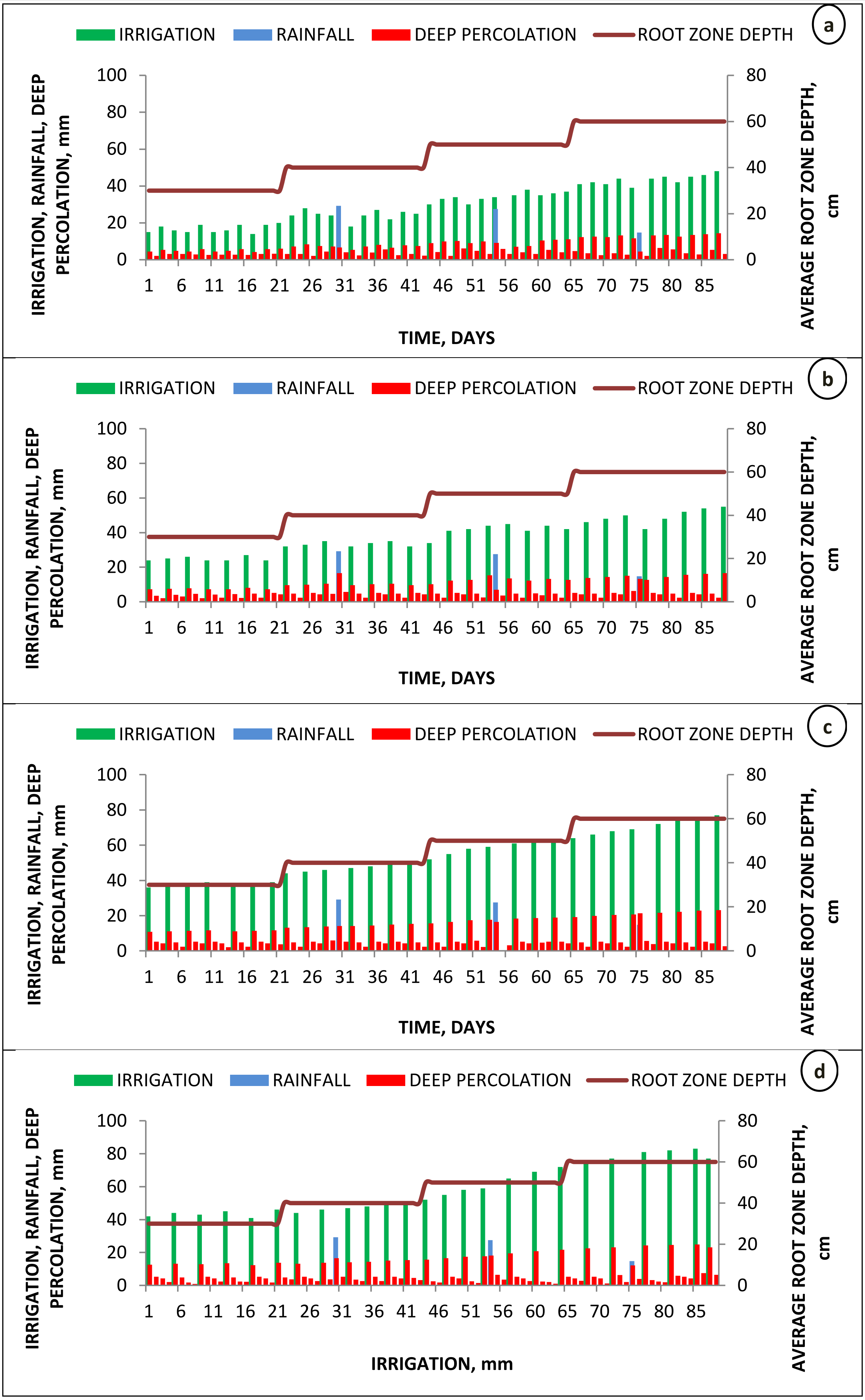

Fig. 3: Deep percolation in response with irrigation under furrow irrigation at (a) 20% MAD, (b) 30% MAD, (c) 40% MAD, (d) 50% MAD levels

Relationship between deep percolation and depth of irrigation at different MAD levels

Relationships between depths of irrigation and deep percolation at different MAD levels have been described through various relation functions.

Irrigation has been applied to the okra plots through pipe lines installed in the field at the proposed MAD levels (20%, 30%, 40% and 50%) taking the average root zone depth during the growth stages of the crop into consideration.

Irrigation at 20% MAD level

In case of furrow irrigation at 20% MAD level, it was observed from the lysimeter readings that total deep percolation bears a linear relationship with the depth of irrigation or effective rainfall. The strong relationship between the two parameters is best described by a high coefficient of determination (R^2) value (R^2 = 0.78) .The relation function is expressed as:

$$DP = 0.1738 \times I + 1.2614 \quad (1)$$

Where,

DP = Total depth of deep percolation, mm

I =Depth of irrigation, mm

Numerical values 0.1738 and 1.2614 in Eq.1 indicate the slope and intercept of the straight line respectively.

A similar trend at different MAD levels relationship between depth of irrigation and depth of percolation was obtained and regression models were developed which are shown in Table 1 below.

Table 1: Regression equation under furrow irrigation at various MAD levels

Parameters	Relationship	Regression equation	Coefficient of Determination (R^2)
20% MAD	Linear	$DP = 0.1738 \times I + 1.2614$	0.78
30% MAD	Linear	$DP = 0.0969 \times I + 1.2736$	0.79
40% MAD	Linear	$DP = 0.2635 \times I + 1.3908$	0.83
50% MAD	Linear	$DP = 0.0726 \times I + 1.9205$	0.82

It was observed that under furrow irrigation method, deep percolation rate has a strong agreement with irrigation depth. From the relationship developed at different MAD levels, it was evident that the slope and the intercepts of each equation are varying in a specific pattern. It was like the slope of the straight line is becoming flatter as the MAD level was increasing from 20 to 50%. On the other hand, it points out that the value of deep percolation was decreasing as the MAD level is increasing.

Water use efficiency (WUE)

Yield of hybrid okra crop obtained under furrow irrigation method at different MAD levels was depicted through Fig. 4. Water use efficiency computed basing upon grain yield per unit use of water was recorded to be the highest at 50% MAD level (15.51 kg/ha-mm) as compared to 50 percent MAD level (13.9 kg/ha-mm). It was interesting to note that the WUE is increasing with increase in MAD level from 20 to 50 percent.

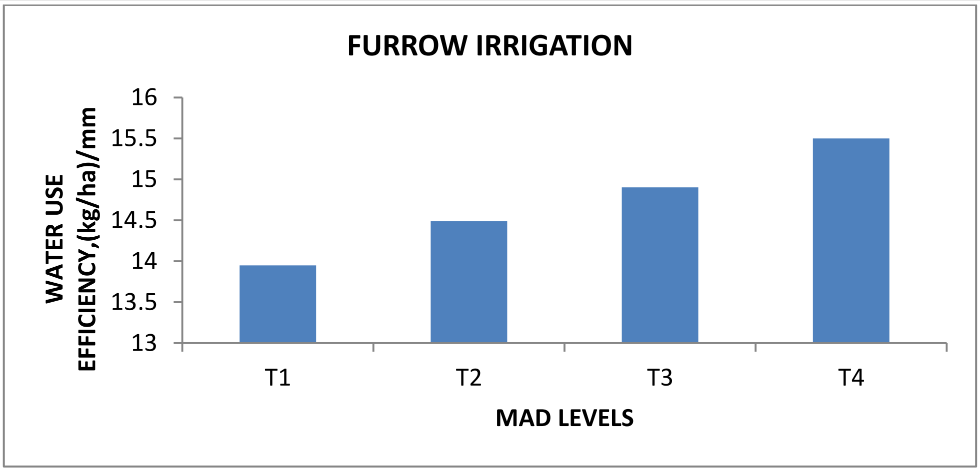

Fig. 4: Water use efficiency at different MAD levels under furrow irrigation

CONCLUSION

The water use efficiency of okra crop is maximum (14.71 kg/ha-mm) at 50 % MAD level under furrow irrigation method. It may be concluded that deep percolation losses are minimum at this MAD level. Hence, there is no need to adopt lower range MAD levels in any of the irrigation practices as frequent irrigation events increase the deep percolation losses. Deep percolation loss increases as the depth of irrigation increases. Further, total deep percolation loss at 20% MAD level is maximum as compared to 30%, 40% and 50% MAD level irrespective of the method of irrigation to okra crop in loamy sand soil. Deep percolation rate declines with time following an irrigation event irrespective of the method of irrigation.

RECOMMENDATIONS

In the study only four MAD levels are taken under irrigation practices. To get more precise estimation of deep percolation, more number of MAD levels needs to be tried with. Regression models have been developed for computation of DP losses under various irrigation methods and at various root zone depths and MAD levels. A physical model to describe the water movement scenario through the soil profile would have been more acceptable.

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