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Irrigation Management Strategy for Vegetable Crops by using Harvested Rainwater under Stressed Condition

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Abstract **– Rainwater is perhaps the most important natural resource in rainfed agriculture. In the North Eastern Ghat Zone of Odisha, farmers do not feel comfortable for growing vegetables during Rabi season due to lack of irrigation facility. Farmers can grow vegetable if they can harvest the rainwater in the farm pond during Kharif season and utilize this harvested water effectively for irrigation purposes during Rabi season. In this context an experiment was designed to study different irrigation management strategy of harvested water for the four major vegetable crops such as cauliflower, tomato, french bean and radish during the Rabi season of 2015-16. Three irrigation treat--ments were maintained based on predefined levels of maximum allowable depletion (MAD) of available soil water (ASW). The treatments were 10% (I_1), 40% (I_2) and 60% (I_3) MAD of ASW. The highest yield was found when irrigation was applied at 10% MAD of ASW (I_1) for all the four vegetable crops such as for cauliflower (65 q/ha), tomato (128.5 q/ha), french bean (62 q/ha) and radish (192 q/ha). Highest yield in all the vegetable crops were found in case of 10% MAD of ASW (I_1) and low yield were found in case of 60% MAD of ASW (I_3). It was observed that as the soil water stress in the root zone increases, the yield parameter decreases. However the soil water stress up to 40% depletion of ASW did not affect the yield parameters very much. Whereas, the highest water use efficiency (WUE) were found when irrigation were applied at 40% MAD of ASW for all the vegetable crops. Under stressed condition, when soil water stress is imposed during non-critical stages of growth, irrigation is to be applied at 40% MAD of ASW for these four major vegetable crops.**

Keywords **– Harvested Water, Maximum Allowable Depletion, Available Soil Water, Water use Efficiency.**

I. INTRODUCTION

Water is essential for crop production, and any shortage has an impact on final yields. In case of situations where water supply is limited, the irrigation demand of the entire cropping pattern cannot be met fully. In these conditions, deliberate under irrigation, also known as deficit irrigation can play a major role. The Kandhamal district of Odisha comes under the North Eastern Ghat Zone of Odisha. The distribution of rainfall is highly erratic during *Kharif* season. Limited and erratic rainfall in the rainfed area creates moisture stress conditions during the various critical growth stages of crop life, resulting in severe yield reduction. In the rainfed areas of North Eastern Ghat Zone of Odisha, even when the rainfall is high, most of the rainwater lost as runoff and very litter quantity of rainwater is available for the crop production. In this zone, farmers do not feel comfortable for growing vegetables during Rabi season due to lack of irrigation facility. Farmers can grow vegetable if they can harvest the rainwater during Kharif season in the farm pond and utilize this harvested water effectively for the life saving irrigation purpose [5], [9], [11].

Dwindling water resources and increasing food requirements require greater efficiency in water use, both in rainfed and in irrigated agriculture. Regulated deficit irrigation provides a means of reducing water consumption while minimizing adverse effects on yield [8]. By deficit irrigation, crops are deliberately under irrigated during plant growth stages that are relatively insensitive to water stress [6]. Identifying growth stages of a particular cultivar under local conditions of climate and soil fertility allows irrigation scheduling to maximize crop yield and most efficient use of scarce water resources [3].

Scarce water resources and growing competition for water will reduce its availability for irrigation. At the same time, rising cost of irrigation pumping, low commodity prices, inadequate irrigation system capacities and limited irrigation water supplies are among the reasons that prompt many irrigators to deliberately apply less water than is required to obtain maximum yield [2], [7]. The goal of effective management of irrigation water is to enhance economic returns with limited use of water and/or energy. Therefore, the crop should be irrigated with required quantities of water during the moisture sensitive period of flowering and yield formation stages, yet allowing moderate stress at vegetative and maturity stages produce the optimum yield with maximum water use efficiency and water economy in most of the crops [10].

In this context an experiment was designed to study the effect of different irrigation management strategy on yield parameters of the four major vegetable crops such as cauliflower, tomato, french bean and radish by using harvested rainwater during the Rabi season of 2015-16. The study is mainly focused on different irrigation scheduling with reference to getting optimum yield with minimum water used.

II. MATERIALS AND METHODS

The experiment was conducted in the experimental farm of the All India Coordinated Research Project for Dryland Agriculture, Phulbani, Odisha, India. It is located in North Eastern Ghat Zone of Odisha of latitude of 19^0 34' to 20^0 34' North, longitude of 80^0 30' to 84^0 35' East and an elevation of 518 m with respect to the mean sea level. The soil at the experimental site was sandy loam and slightly acidic (pH - 5.3 to 6.5). The detail soil texture and physico-chemical properties in different soil layers of research farm are given in Table 1. The soil of the

experimental site is having filed capacity of 13.2%, wilting point of 5.0% on weight basis and bulk density of 1.25 gcm^{-3}. The experimental site falls under the sub-humid subtropical region with average annual rainfall of 1407 mm, concentrated mostly in the months of June to October.

The normal rainfall in the Research farm is 1407 mm which includes 65 rainy days. The total rainfall during 2015 was 1060.6 mm (60 rainy days) which is 24.7 % less rainfall than the normal rainfall respectively. The experimental site received rainfall of 778.8 mm during *Kharif* season in 36 rainy days. The normal date of onset of monsoon is 10th June whereas normal date of cessation of monsoon is 6th October. During 2015, the date of onset of monsoon occurred on 12th June whereas the date of cessation of monsoon occurred on 22nd September. The weekly rainfall distribution of the experimental site is given in Fig. 1.

Improved varieties of crops such as Cauliflower (Var. Hybrid Megha), Tomato (Var. Hybrid Lakhsmi), French bean (Var. Saguni) and Radish (Var. Pusa Chetki) have been taken for the experiment. The experiment was conducted in split plot design in which different vegetable crops were taken in main plot and irrigation treatments were taken in sub plot. The different vegetable crops such as cauliflower, tomato, french bean and radish are taken in the main plot. Three irrigation treatments were maintained based on predefined levels of maximum allowable depletion (MAD) of available soil water (ASW). The different irrigation treatments taken in the sub plots were given below.

- I_1 - 10% maximum allowable depletion (MAD) of available soil water (ASW).
- I_2 - 40% maximum allowable depletion (MAD) of available soil water (ASW) and
- I_3 - 60% maximum allowable depletion (MAD) of available soil water (ASW).

The irrigation treatments were initiated after the completion of the early vegetative stage. The irrigation was applied from the farm pond in which runoff water were harvested during the Kharif season. In order to asses the depth and time variation of soil moisture under different scheduling of irrigation, soil moisture was measured periodically in 0-30 cm soil profile by gravimetric method. The crop experiments were conducted in 36 experimental plots of 5m × 4m size. There were three replications for each treatment. The seed rate of tomato, cauliflower, French bean and radish are 0.5 kg ha^{-1}, 0.5 kg ha^{-1}, 75 kg ha^{-1} and 12.5 kg ha^{-1} respectively. Row to row spacing and plant to plant spacing for all tomato and cauliflower crops are maintained as 60 cm and 45 cm respectively. Row to row spacing of french bean and radish are 45 cm and 30 cm respectively whereas plant to plant spacing of french bean and radish are 25 cm and 10 cm respectively.

Periodical observation of growth and yield parameter was recorded during Rabi season of 2015-16. The yield data were necessary for economic analysis and estimation of water use efficiency. In order to compute the profitability of different crops under different irrigation treatments, the net returns and benefit-cost (B:C) ratio were calculated. The net returns (Rs/ha) were computed as a difference of gross returns and cost of cultivation (Rs/ha) for each treatment. The B:C ratio was derived as a ratio of gross returns and cost of cultivation for each treatment. The data were subjected to paired "t" test analysis for determining the significance of difference between the treatments and to draw valid conclusions. The level of significance used was p = 0.05. Data were analyzed as per split plot design [4]. The values of Radish Equivalent Yield (REY) were computed by using the formula [1].

$$REY = \frac{(Y_r \times P_i)}{P_m} \qquad (1)$$

Where, Y_r is yield of replace crop, P_r is price of replace crop and P_m is price of Radish

III. Results and Discussion

The soil moisture for 0-30 cm soil profile was determined by conventional gravimetric method**.** The changes in soil moisture in soil layer 0-30 cm in

Table 1. Soil texture and physico-chemical properties in different soil layers of the experimental site.

Depth (cm)	Sand (%)	Silt (%)	Clay (%)	Textural Class	pH	EC (dS/m)	OC (%)
0-15	68.2	14.5	17.3	Sandy loam	5.3	0.07	0.25
15-30	65.2	13.2	21.6	Sandy clay loam	5.2	0.03	0.17
30-45	63.8	11.8	24.4	Sandy clay loam	6.0	0.02	0.18
45-60	51.2	10.5	38.3	Sandy clay	6.3	0.02	0.12
60-90	48.8	10.8	40.4	Sandy clay	6.5	0.02	0.08

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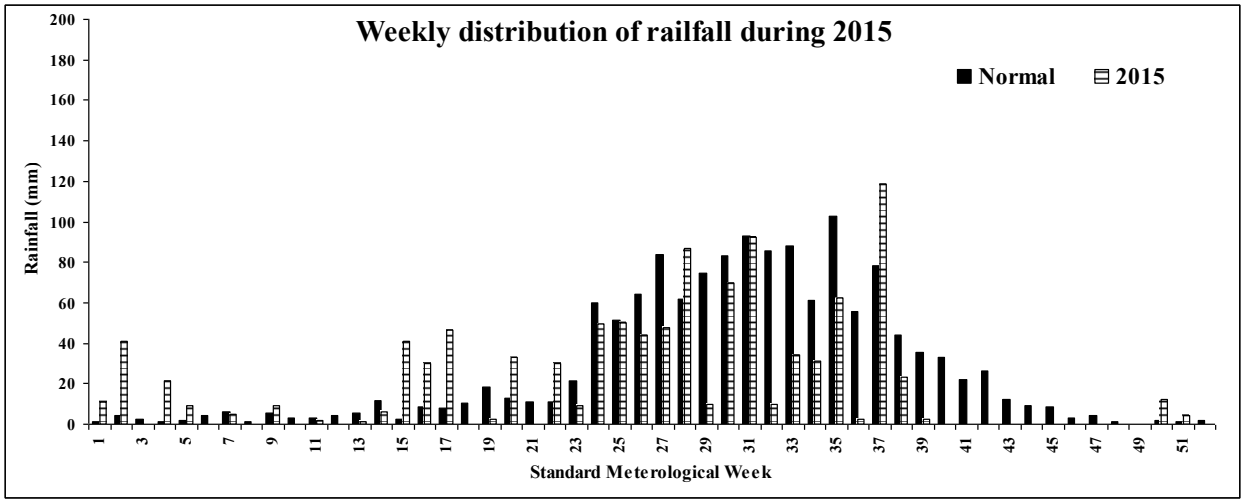

Fig. 1. Weekly rainfall distribution of the experimental site during 2015

different irrigation treatments for cauliflower, tomato, french bean and radish crop during 2015-16 is given in the Table 2. The cyclic variation of soil moisture is more in I_1 treatment that the I_2 and I_3 treatments. This is due to the irrigation of 4 times were applied during I_1 treatment whereas the irrigation of 2 times were applied during I_3 treatment. Irrigations of 3 times were applied during I_2 treatments of all the vegetable crops. The temporal variation of soil water was observed to be similar during all the four vegetable crops.

The economics and water use efficiency of different vegetable crops under different irrigation treatment is given in the Table 3. The results of the experiment show that highest yield was found when irrigation was applied at 10% maximum allowable depletion of available soil water for all the four vegetable crops such as for cauliflower (65 q/ha), Tomato (128.5 q/ha), French bean (62 q/ha) and Radish (192 q/ha). Highest yield in all the vegetable crops were found in case of 10% MAD of ASW (I_1) and low yield were found in case of 60% MAD of ASW (I_3).

The interaction effects were studied among the different irrigation treatments and different vegetable crops (Table 4). The yields of the vegetable crops were expressed in Radish Equivalent yield (REY). The results revealed that different type of irrigation treatments significantly influence the radish equivalent yield of different vegetable crops. Among the vegetables, higher REY was found in tomato crop followed by cauliflower, french bean and radish crop in all the irrigation treatments.

The yields of the different crops are expressed as radish equivalent yield (REY). The Radish Equivalent Yield (REY) of different vegetable crops under different irrigation treatment is given in the Table 4. It was observed that as the soil water stress

Table 2. Soil moisture variation (w/w %) as affected by different irrigation treatment during 2015-16.

Treatment		Date										
Crop	**Irrigation treatments**	**15th Nov**	**22nd Nov**	**30th Nov**	**7th Dec**	**15th Dec**	**22nd Dec**	**30th Dec**	**7th Jan**	**15th Jan**	**22nd Jan**	**30th Jan**
Cauliflower	I_1	13.8	6.8	14.4	7.5	6.2	12.8	7.1	6.7	13.2	6.8	5.9
	I_2	13.9	6.9	5.8	14.1	7.2	6.2	5.2	14.2	7.2	6.1	5.2
	I_3	14.1	7.2	6.2	5.0	5.0	14.3	7.6	6.5	6.0	5.2	5.0
Tomato	I_1	13.9	6.9	14.5	7.6	6.2	12.9	7.2	6.8	13.3	6.9	5.9
	I_2	13.9	6.9	5.7	14.1	7.2	6.3	5.2	14.2	7.3	6.1	5.1
	I_3	14.2	7.2	6.3	5.4	5.2	14.3	7.7	6.5	6.0	5.4	5.1
French bean	I_1	13.9	6.8	14.4	7.5	6.2	12.9	7.2	6.8	13.3	6.9	5.9
	I_2	14.0	6.7	5.7	14.2	7.3	6.2	5.3	14.2	7.2	6.1	5.2
	I_3	14.0	7.0	6.1	5.2	5.0	14.3	7.6	6.5	6.0	5.2	5.0
Radish	I_1	13.8	6.8	14.4	7.5	6.2	12.8	7.1	6.7	13.2	6.8	5.9
	I_2	14.2	6.7	5.9	14.1	7.2	6.2	5.2	14.2	7.2	6.1	5.2
	I_3	14.3	7.2	6.2	5.0	5.0	14.4	7.7	6.6	6.1	5.3	5.1

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Table 3. Economics and water use efficiency of crops under different treatments.

Treatment		Yield (q/ha)	REY (q/ha)	Cost of Cultivation (Rs/ha)	Gross Income (Rs/ha)	Net Income (Rs/ha)	B:C ratio	WUE (kg/ha -mm)
Crop	Irrigation method							
Cauliflower	I_1	65.0	203.0	60000	162500	102500	2.7	16.25
	I_2	58.0	181.2	59000	145000	86000	2.5	18.12
	I_3	44.0	137.5	58000	110000	52000	1.9	15.72
Tomato	I_1	128.5	321.0	75000	257000	182000	3.4	21.42
	I_2	118.0	295.0	74000	236000	162000	3.2	23.60
	I_3	92.0	230.0	73000	184000	111000	2.5	20.44
French bean	I_1	62.0	194.0	65000	155000	90000	2.4	15.5
	I_2	55.0	172.0	64000	137500	73500	2.1	17.19
	I_3	41.0	128.0	63000	102500	39500	1.6	14.64
Radish	I_1	192.0	192.0	40000	153600	113600	3.8	64.0
	I_2	176.0	176.0	39000	140800	101800	3.6	73.3
	I_3	124.0	124.0	38000	99200	61200	2.6	62.0

REY – Radish Equivalent Yield; Price (Rs./kg): Cauliflower-25/-; Tomato-20/-; French bean -25/-; Radish – 8/-
Rain water available – 26 mm; Cost of irrigation has been included in the cost of cultivation

in the root zone increases, the yield parameter decreases. However the soil water stress up to 40% depletion of ASW did not affect the yield parameters very much. Whereas, the highest water use efficiency (WUE) were found irrigation were applied at 40% MAD of ASW for all the vegetable crops. The water use efficiency of I_2 irrigation treatment of cauliflower, tomato, french bean and radish were found to be 18.12, 23.6, 17.19 and 73.3 respectively. Under water scarcity condition, when soil water stress is imposed during non-critical stages of growth, irrigation is to be applied at 40% maximum allowable depletion of available soil water for these four major vegetable crops. Thus, the results and the

Table 4. Radish Equivalent Yield (q/ha) of vegetable crops under different irrigation treatments.

Crop	Irrigation Treatment			
	I_1	I_2	I_3	Mean
Cauliflower	203.0	181.2	137.5	173.9
Tomato	321.0	295.0	230	282.0
French bean	194.0	172.0	128	164.67
Radish	192.0	176.0	124.0	164.0
Mean	227.5	206.5	154.88	
		SE (±m)	C.D. (0.05)	
Crop (C)		2.29	7.92	
Irrigation Treatment (I)		2.07	6.03	
C X I		4.13	12.05	

methodology adopted in this study would be very useful to researchers, farmers, land managers, state agricultu--ral departments, and other stakeholders not only in India but also across the world under similar climatic situations.

IV. Conclusions

The following conclusions could be drawn from the results of the study.

1. Highest yield were found when irrigation were applied at 10% MAD of ASW for all the vegetable crops such as cauliflower, tomato, french bean and radish.
2. The highest water use efficiency was found irrigation was applied at 40% MAD of ASW for all the vegetable crops.
3. Under water scarcity condition, when soil water stress is imposed during non-critical stages of growth, irrigation is to be applied at 40% MAD of ASW for these four major vegetable crops.

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