

Original Research Article

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## Irrigation Efficiency and Water Production Function of Furrow Irrigation Influenced by Depth in Wheat Crop

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### ABSTRACT

#### Keywords

Furrow Irrigation, MAD, Consumptive use, Water production function

#### Article Info

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A field study was conducted on irrigation efficiency and water production function in wheat crop at SVCAET and RS IGKV Raipur (C.G). The treatment included were four main treatments of method of Raised bed furrow irrigation M<sub>1</sub> (15 cm furrow depth), M<sub>2</sub> (20 cm furrow depth), M<sub>3</sub> (25 cm furrow depth) and M<sub>4</sub> (border irrigation system (control)) under the three sub-treatments of maximum allowable depletion (MAD) T<sub>1</sub> (Irrigation at 40% MAD), T<sub>2</sub> (Irrigation at 50% MAD) and T<sub>3</sub> (Irrigation at 60% MAD) in four row crop. These treatments were replicated three times. Strip Plot Design was adopted by considering the moisture depletion and method of furrow irrigation as treatment. Mean water application efficiency was found maximum under M<sub>2</sub> treatment. However maximum water distribution efficiency found under M<sub>1</sub> then M<sub>2</sub>. The water use efficiency recorded maximum (9.50 kg ha<sup>-1</sup> mm<sup>-1</sup>) under M<sub>2</sub>T<sub>2</sub>. Similarly in border system maximum (8.98 kg ha<sup>-1</sup> mm<sup>-1</sup>) recorded in M<sub>4</sub>T<sub>2</sub>.

### Introduction

Water is one of the most essential natural resources for sustaining life and it is likely to become critically scarce in the coming decades, due to continuous increase in its demands, rapid increase in population and expanding economy of the country.

Water is becoming increasingly scarce due to growing demand in the domestic and industrial sectors so there is a need to develop water saving irrigation techniques that require less irrigation input than the traditional method. There is a new method of wheat sowing in which wheat is sown on raised beds

called FIRB (Furrow Irrigated Raised Bed) system. This method is being followed in many wheat growing countries. Bed planting of wheat helps in saving of 25–30 % water and reducing costly herbicide application by mechanical weeding of grassy weeds (Gill and Jat, 2007).

Furrow Irrigated Raised Bed irrigation system consists of alternate furrows and flat beds in ridges. Better irrigation efficiency can be achieved by adopting the bed and furrow irrigation technique for growing of wheat and other row crops, with many benefits over conventional basin irrigation methods.

**Materials and Methods**

A fields experiments was conducted at the Research Farm of SVCAET&RS, IGKV, Raipur, CG during the rabi season. The bulk density of the soil was 1.48 g/cm<sup>3</sup>, field capacity was 27%, permanent wilting point was 13.15% and the basic infiltration rate of the soil was 0.58-0.66 cm/hr. The irrigation efficiency and water production function in wheat crop were studied in furrow irrigated raised bed with variable furrow sections under three moisture regimes, viz. Irrigation at 40, 50 and 60% MAD (Maximum Allowable Depletion). In this system, three different depth of furrow at 15, 20 and 25 cm were made and the four row of crops at 22.5 cm were planted on top of each bed (Fig. 1). Strip plot design was adopted by considering the moisture depletion and method of furrow irrigation as treatments. These were compared with border irrigation method. Irrigation water was applied in furrows.

**Irrigation efficiency**

Irrigation efficiency is the effectively utilization of the available water supply in different methods of irrigation. Proper field preparation, design of irrigation system and the skill of irrigator are the most common factor which increases irrigation efficiency.

**Water application efficiency**

Water application efficiency is the measurement of efficiently water applied from field channel to field and defined as follows (Michael, 1978):

$$E_a = \frac{W_s}{W_f} \times 100$$

Where,

$E_a$  = water application efficiency, (%)

$W_s$  = water stored in the root zone of the plant

$W_f$  = water delivered to the field (at the field supply channel)

**Water storage efficiency**

Water storage efficiency relates how completely the water needed prior to irrigation has been stored in the root zone during irrigation. It is defined as:

$$E_s = \frac{W_s}{W_n} \times 100$$

Where,

$E_s$  = water storage efficiency(%)

$W_s$  = water stored in the root zone during irrigation

$W_n$  = water needed in the root zone prior to irrigation

**Water production function**

The relationship between water use efficiency and grain yield was developed for water production function.

**Consumptive use**

Consumptive use, often called evapotranspiration, is the amount of water used by the vegetative growth of a given area in transpiration and building up of plant tissues and evaporation from soil and plant surfaces. Since the difference between evapotranspiration and consumptive use is usually less than 1%. It is assumed equal to be ET.

Seasonal consumptive use ( $C_u$ ) is calculate from the following relationship:

$$C_u = \sum_{k=1}^N (E_o \times 0.8) + \sum_{i=1}^n \frac{M_1^i - M_2^i}{100} A_i \cdot D_i + E_R$$

Where,

$C_u$  = Seasonal consumptive use in mm

$N$  = Number of layers samples in root zoon depth  $D$ ,

$M_{1i}$  = Soil moisture percent at the time of first sampling in  $i^{th}$  layer,

$M_{2i}$  = Soil moisture percent at the time of second sampling in  $i^{th}$  layer,

$A_i$  = Apparent specific gravity of the  $i^{th}$  layer of the soil,

$D_i$  = Depth of  $i^{th}$  layer of the soil in mm,

$E_R$  = Effective rainfall

$N$  = Time interval in days

$E_0$  = Pan evaporation in mm from day of irrigation to day when Soil samples were taken in wet soil.

### **Water Use Efficiency (WUE)**

Eventually water use efficiency of crop has been expressed as the ratio of grain yield ( $\text{kg ha}^{-1}$ ) to the consumptive use (mm) of crop (Michael, 1978):

$$WUE = \frac{\text{Grain yield}(\text{kg/ha})}{\text{consumptive use}(\text{mm})}$$

## **Results and Discussion**

### **Irrigation efficiencies**

Irrigation efficiency is one of the major factor which indicates the performance of the irrigation system. Water application, distribution and water storage efficiencies were calculated in this study.

### **Water application efficiency**

The mean water application efficiency varied from 52.76 to 66.14. per cent (Table 1). The maximum value of water application efficiency was measured 66.14 per cent in 20

cm furrow depth and minimum value were recorded 62.46 per cent in 15 cm furrow depth. In border irrigation system water application efficiency was 52.76 percent recorded (Fig. 2).

### **Water storage efficiency**

Water storage efficiency was recorded maximum (60.53 per cent) in 25 cm furrow depth treatment. The efficiency was found minimum (57.5 per cent) in 15 cm furrow depth treatment (Table 2).

The mean water storage efficiency varied from 57.50 to 60.53 per cent in furrow irrigated raised bed system. In furrow irrigated raised bed system 25 cm furrow depth recorded maximum efficiency than the 15 and 20 cm furrow depth. In the border irrigation system the water storage efficiency was approximately same as 25 cm furrow depth treatment. The mean water storage efficiency has been shown in Fig 3.

### **Water distribution efficiency**

The mean water distribution efficiency varied from 94.07 to 89.74 per cent. The mean maximum (94.07 per cent) water distribution efficiency was recorded under 15 cm furrow depth and the minimum (89.74 per cent) recorded in 25 cm furrow depth (Table 3).

Water application, storage and distribution efficiencies for different treatments have been shown graphically in Fig. 4. to depict overall effect of individual treatment on these efficiencies. It can be seen from the Fig. 5 that the water application efficiency was observed the highest in 25 cm furrow depth while the water storage efficiency and distribution efficiency were found maximum in 15 cm furrow depth and 25 cm furrow depth comparatively border irrigation system.

**Table.1** Water application efficiency of irrigation

Irrigation system	Water application efficiency			
	I Irrigation	II Irrigation	III Irrigation	Mean
M1	62.41	61.24	63.72	62.46
M2	65.55	66.47	66.41	66.14
M3	64.59	64.52	65.14	64.75
M4	52.87	50.95	54.45	52.76

**Table.2** Water storage efficiency of irrigation

Irrigation	Water storage efficiency			
	I Irrigation	II Irrigation	III Irrigation	Mean
M1	57.92	59.12	55.48	57.50
M2	59.52	59.89	58.25	59.22
M3	58.65	60.37	62.59	60.53
M4	60.52	59.89	61.28	60.56

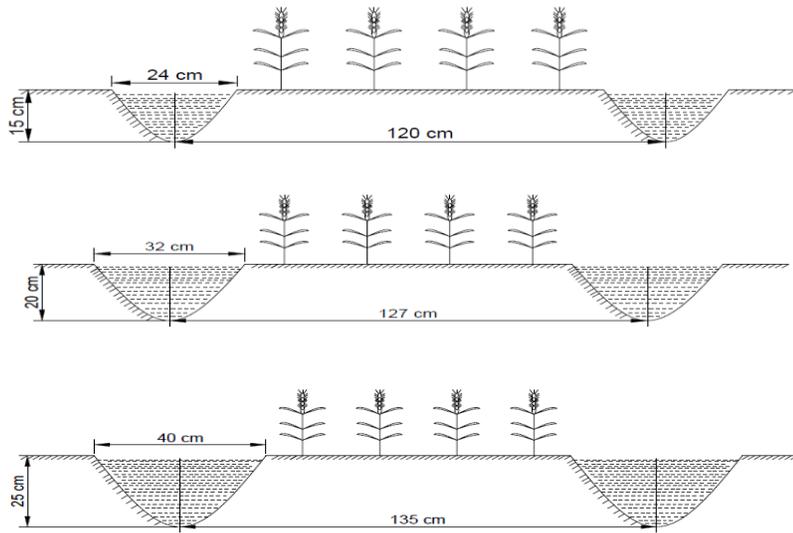
**Table.3** Water distribution efficiency

Irrigation	Water storage efficiency			
	I Irrigation	II Irrigation	III Irrigation	Mean
M1	93.25	94.12	94.85	94.07
M2	90.24	89.47	93.14	90.95
M3	88.48	90.28	90.47	89.74
M4	80.47	78.63	80.74	79.95

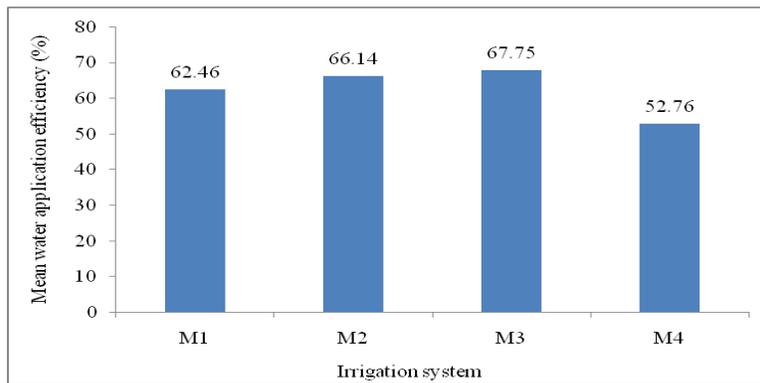
**Table.4** Seasonal consumptive use and water use efficiency under different treatments

Treatment	Seasonal Consumptive use (mm)	Water use efficiency (kg ha <sup>-1</sup> mm <sup>-1</sup> )
M1T1	369.45	5.66
M2T1	372.42	6.24
M3T1	362.12	6.52
M4T1	288.00	6.72
M1T2	278.00	8.48
M2T2	296.45	9.50
M3T2	283.00	9.17
M4T2	284.90	8.98
M1T3	256.10	5.08
M2T3	252.21	7.54
M3T3	246.00	7.12
M4T3	251.40	6.48

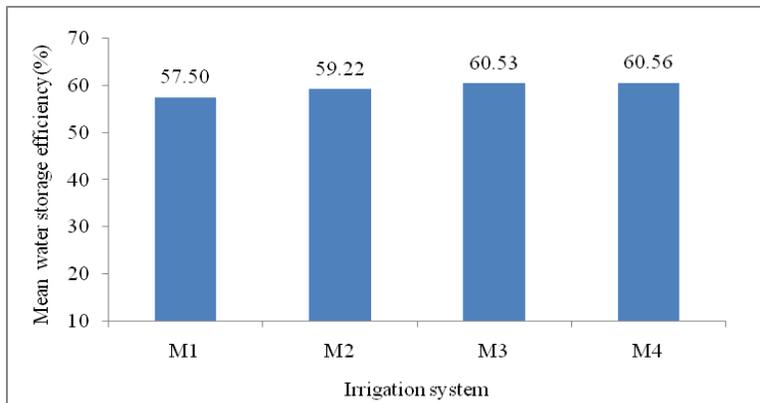
**Fig.1** 15, 20 and 25 cm depth of furrow irrigated raised bed system



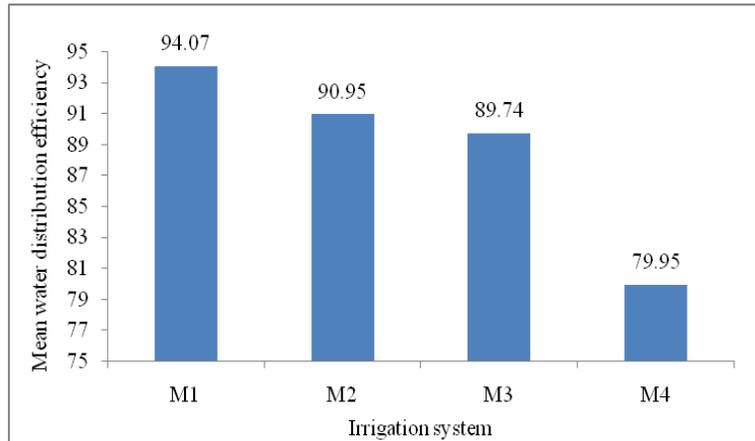
**Fig.2** Mean water application efficiency



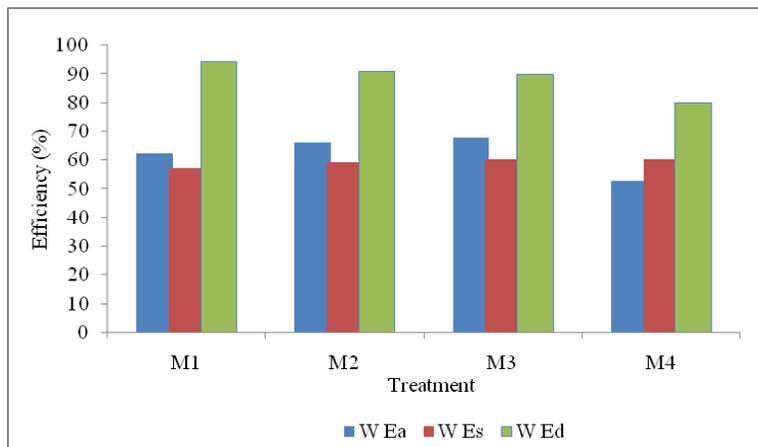
**Fig.3** Mean water storage efficiency



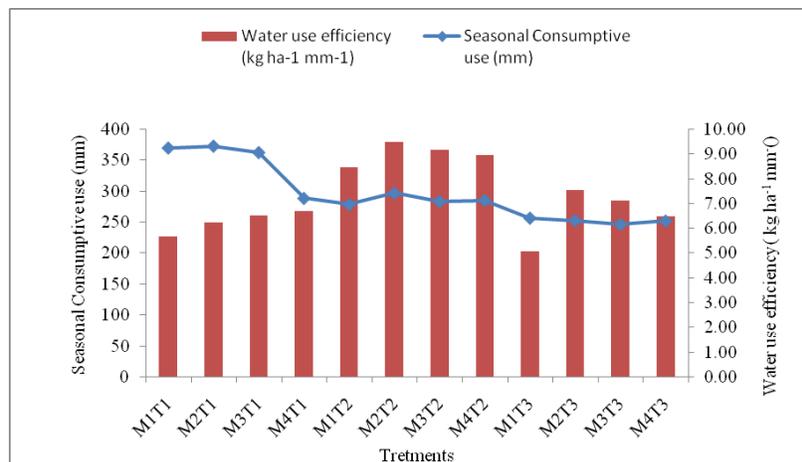
**Fig.4** Mean water distribution efficiency



**Fig.5** Water application efficiency (W Ea), storage efficiency (W Es) and distribution efficiency (W Ed) for different treatment



**Fig.6** Seasonal consumptive use and water use efficiency



## Water production function

### Consumptive use

The seasonal water supply is determined and evaluated by the seasonal water use efficiency. Consumptive use for furrow irrigated raised bed system and borders was estimated by moisture depletion method. The moisture depletion from sowing to harvesting was calculated.

The moisture depletion for the days between irrigation applied and moisture samples taken was considered 0.8 of pan evaporation. The seasonal consumptive use varied between 246.00 to 372.42 mm. In furrow irrigated raised bed system 20 cm furrow depth at 40% MAD treatment recorded the highest value (372.42 mm). In border irrigation method treatment at 40% MAD recorded highest value (288.00 mm) (Fig. 6 and Table 4).

### Water use efficiency

The water use efficiency varied from 5.08 to 9.50 kg ha<sup>-1</sup> mm<sup>-1</sup> for furrow irrigated raised bed system and similarly for border it varied from 6.48 to 8.98 kg ha<sup>-1</sup> mm<sup>-1</sup>. In furrow irrigated raised bed system the maximum water use efficiency found in 9.50 kg ha<sup>-1</sup> mm<sup>-1</sup> in 20 cm furrow depth under 50% MAD and minimum recorded in 15 cm furrow depth under 60% MAD (5.08 kg ha<sup>-1</sup> mm<sup>-1</sup>). In border irrigation Highest (8.98 kg ha<sup>-1</sup> mm<sup>-1</sup>) recorded in 50% MAD and minimum (6.48 kg ha<sup>-1</sup> mm<sup>-1</sup>) in 40% MAD.

Thus it can be concluded that the data presented from the research shows that the seasonal consumptive use varied between 246.00 to 372.42 mm. In furrow irrigated raised bed system 20 cm furrow depth at 40% MAD treatment recorded the highest value (372.42 mm). In border irrigation method treatment at 40% MAD recorded highest

value (288.00 mm). The water use efficiency varied from 5.08 to 9.50 kg ha<sup>-1</sup> mm<sup>-1</sup> for furrow irrigated raised bed system and similarly for border it varied from 6.48 to 8.98 kg ha<sup>-1</sup> mm<sup>-1</sup>.

In furrow irrigated raised bed system the maximum water use efficiency found in 9.50 kg ha<sup>-1</sup> mm<sup>-1</sup> in 20 cm furrow depth under 50% MAD and minimum recorded in 15 cm furrow depth under 60% MAD (5.08 kg ha<sup>-1</sup> mm<sup>-1</sup>). In border irrigation Highest (8.98 kg ha<sup>-1</sup> mm<sup>-1</sup>) recorded in 50% MAD and minimum (6.48 kg ha<sup>-1</sup> mm<sup>-1</sup>) in 40% MAD.

Saving in irrigation water was calculated over the treatments from total depth of applied water. The maximum water saving was obtained 8.33 cm furrow irrigated raised bed system and 4.02 cm in border system in 50% MAD treatment over 40% MAD. Similarly, the maximum water saving was obtained 5.61 cm furrow irrigated raised bed system and 3.39 cm in border system in 60% MAD treatment over 50% MAD.

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