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**Shabana**

Department of Agronomy,  
Dr. Rajendra Prasad Central  
Agricultural University, Pusa,  
Bihar, India

**Vinod Kumar**

Professor-cum-Chief Scientist,  
Department of Agronomy,  
RPCAU, Pusa, Bihar, India

**Bharati Upadhaya**

Farm Manager, M. Sc (Ag)  
Agronomy, KVK, Samastipur,  
RPCAU, Pusa, Bihar, India

**Sweeti Kumari**

Department of Agronomy,  
Dr. Rajendra Prasad Central  
Agricultural University, Pusa,  
Bihar, India

**Rahul Kumar**

Department of Soil Science and  
Agricultural Chemistry, BAU,  
Sabour, Bihar, India

**Corresponding Author:****Bharati Upadhaya**

Farm Manager, M. Sc (Ag)  
Agronomy, KVK, Samastipur,  
RPCAU, Pusa, Bihar, India

## Yield, water use efficiency and water productivity of rice (*Oryza sativa* L.) relative to irrigation management and crop establishment methods

**Shabana, Vinod Kumar, Bharati Upadhaya, Sweeti Kumari and Rahul Kumar**

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**Abstract**

A field experiment was conducted at Crop Research Centre, RPCAU, Pusa, Bihar during *Kharif*, 2017. The soil of the experimental plot was sandy loam in texture with low in available N, P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O. The experiment was laid out in split plot design and replicated thrice. A total of twelve treatment combinations were used *viz.*, three irrigation levels (I) in main plots and four crop establishment methods (E) in sub-plots. Irrigation level includes I<sub>1</sub> - Continuous submergence throughout crop growth, I<sub>2</sub> - Saturation maintenance upto PI and (5±2cm) after PI and I<sub>3</sub> - Alternate wetting and drying (5 cm irrigation at 3 DADPW) up to PI and (5±2 cm) after PI while the methods of establishment includes E<sub>1</sub> - Normal transplanting, E<sub>2</sub> - Direct wet seeding on puddled soil, E<sub>3</sub> - Direct dry seeding and E<sub>4</sub> - Broadcasting on un-puddled soil. Grain as well as straw yield were significantly influenced by different crop establishment methods but not significantly affected by different irrigation levels. Water use efficiency and water productivity were also significantly affected by different crop establishment methods but water productivity was not significantly affected by different irrigation managements.

**Keywords:** Yield, WUE, water productivity, irrigation levels, crop establishment, rice

**Introduction**

Rice (*Oryza sativa* L.) is one of the most staple food crops for more than half of the world population by providing 25% calories and 20% protein. It accounts for a significant contribution to the total food grain production in India. Rice crop establishment methods are very diverse, and include direct seeding by broadcasting, and transplanting of seedlings at different spacing. These different crop establishment methods lead to differences in the structure of the rice crop canopy, *i.e.* in crop geometry. In the case of a direct-seeded crop established by broadcasting rice seeds, the crop consists of randomly distributed plants with three to five tillers each. Such a crop can thus be seen as a population of tillers that are slightly aggregated at a scale corresponding to the area occupied by one plant. In the case of transplanted rice, the crop consists of uniformly distributed hills, each having 10–40 tillers. A transplanted rice crop, by contrast, can thus be seen as a population of tillers that are strongly aggregated at a scale corresponding to the area occupied by one hill (which is usually larger than the area occupied by one direct-seeded plant). Rice is a water loving crop. So, there is also urgent need to develop-irrigation water saving techniques as well as proper irrigation schedule that requires less irrigation input than the traditional method, which also increase production and productivity of rice crop. To reduce water use in rice systems is an irrigation management practice referred to as Alternate Wetting and Drying (AWD) (Lampayan *et al.*, 2015) [4]. Alternate wetting and drying (AWD) irrigation is water saving irrigation technique in rice production and can be an important adaptation strategy under climate change where water scarcity may become more prevailing. It is a rice management practice that reduces water use by up to 30% and can save farmers money on irrigation and pumping costs. Alternate wetting and drying (AWD) saved more than 50% of irrigated water for both cropping seasons compared with continuous flooding treatment (Nhan, 2015). Focussing on all the prospects, experiment entitled “Yield, water use efficiency and water productivity of rice (*Oryza sativa* L.) relative to irrigation management and crop establishment methods” was conducted.

## Materials and Methods

The experiment was conducted at Crop Research Centre, Dr. Rajendra Prasad Central Agricultural University, Bihar, Pusa in *Kharif*, 2017. The soil was calcareous which was characterized by the presence of 25.9 per cent free calcium carbonate. The soil of the experimental field was sandy loam in texture with low available N (154 kg/ha), P<sub>2</sub>O<sub>5</sub> (19.21 kg/ha) K<sub>2</sub>O (121.00 kg/ha). The experiment was laid out in split plot design with three irrigation levels (I) in main plots and four crop establishment methods (E) in sub-plots and replicated thrice. Irrigation level includes I<sub>1</sub> - Continuous submergence throughout crop growth, I<sub>2</sub>- Saturation maintenance upto PI and (5±2cm) after PI and I<sub>3</sub> - Alternate wetting and drying (5 cm irrigation at 3 DADPW) up to PI and (5±2 cm) after PI while the methods of establishment includes E<sub>1</sub>- Normal transplanting, E<sub>2</sub>- Direct wet seeding on puddled soil, E<sub>3</sub>- Direct dry seeding and E<sub>4</sub>- Broadcasting on un-puddled soil. The yield of grains in the net plot was recorded in kilogram/plot and was later converted into q/ha to obtain the grain yield. Simultaneously, the straw from each net plot was air-dried and weighted. The straw yield, thus converted in q/ha.

Irrigation scheduling was done as per the treatment details. The frequency of irrigation was decided on the basis of irrigation. In each irrigation, 5 cm water applied in the field. Total amount of water (cm) applied to the crop during the crop period was calculated as water requirement. Water Use Efficiency was calculated as the expression of the marketable product (grain) obtained by per unit of water applied to the crop. It can be determined with the help of the following formula:

$$\text{Water use efficiency (kg/ha-cm)} = \frac{\text{Yield (kg/ha)}}{\text{Water requirement (cm)}}$$

Water productivity was calculated for each irrigation treatments and expressed in  $\text{m}^3/\text{m}^3$ . The formula we used to calculate the water productivity is

$$\text{Water productivity} = \frac{\text{Net returns (₹/ha)}}{\text{Total water consumed in m}^3/\text{ha including effective rainfall}}$$

## Results and Discussion

### Grain and Straw yield

Grain and straw yield was not significantly affected by different irrigation managements. However, grain yield obtained with continuous submergence throughout crop growth recorded maximum value (37.22 q/ha) which was followed by saturation maintenance upto PI and (5±2cm) after PI (34.53 q/ha) and alternate wetting and drying (5 cm irrigation at 3 DADPW) upto PI and (5±2 cm) after PI (33.65 q/h). Similar trend was followed in straw yield. While, different crop establishment methods exerted a significant effect on grain yield. The maximum grain yield (40.53 q/ha) was recorded with normal transplanting which was significantly superior to direct wet seeding on puddled soil (35.09 q/ha), direct dry seeding (34.38 q/ha) and broadcasting on un-puddled soil (30.53 q/ha). Similar results were obtained by Sahu *et al.* (2015) [6]. Straw yield was also significantly affected by crop establishment methods. Higher straw yield (58.26 q/ha) was obtained with normal transplanting which was statistically at par with direct wet seeding on puddled soil (50.77 q/ha) and was significantly superior to direct dry

seeding (49.89 q/ha) and broadcasting on un-puddled soil (44.43q/ha).

### Water Use Efficiency

The mean data containing water use efficiency and water productivity have been summarized and presented in Table 2 and Fig. b. Water use efficiency was significantly influenced due to different irrigation managements. The maximum WUE was recorded with alternate wetting and drying (5 cm irrigation at 3 DADPW) upto PI and (5±2 cm) after PI (37.90 kg/ha-cm) which was significantly superior to continuous submergence throughout crop growth (32.26 kg/ha-cm) and was statistically at par with saturation maintenance upto PI and (5±2cm) after PI (35.03 kg/ha-cm). This finding was also corroborate the findings of Fonteh *et al.* (2013) [2]. The water use efficiency with regard to different crop establishment methods was also found to be significant. The maximum water use efficiency was recorded with normal transplanting (44.50 kg/ha-cm) which was significantly superior over rest of the treatments.

### Water Productivity

Water productivity was not significantly influenced due to irrigation management. However, water productivity with alternate wetting and drying (5 cm irrigation at 3 DADPW) upto PI and (5±2 cm) after PI was found to be maximum (4.41 Rs/m<sup>3</sup>) and minimum (3.60 Rs/m<sup>3</sup>) at continuous submergence throughout crop growth. This might be due to less water requirement in case of alternate wetting and drying condition. Gill *et al.* (2014) [3] also confirmed the similar result. Different crop establishment treatments had significant effect on water productivity. Among all the treatments, normal transplanting recorded the maximum water productivity (5.19 Rs/m<sup>3</sup>) which was significantly superior to direct wet seeding on puddled soil (3.17 Rs/m<sup>3</sup>), direct dry seeding (4.17 Rs/m<sup>3</sup>) and broadcasting on un-puddled soil (3.45 Rs/m<sup>3</sup>). This might be due to high water application in transplanted rice and comparatively higher net returns were obtained. Balasubramanian *et al.* (2001) [1] confirmed same result.

**Table 1:** Grain yield (q/ha), straw yield (q/ha), and harvest Index (%) affected by different treatments

Treatments	Grain yield (q/ha)	Straw yield (q/ha)
<b>Irrigation management</b>		
I <sub>1</sub> - Continuous submergence throughout crop growth.	37.22	53.66
I <sub>2</sub> - Saturation maintenance upto PI and (5±2cm) after PI.	34.53	49.97
I <sub>3</sub> - Alternate wetting and drying (5 cm irrigation at 3 DADPW) upto PI and (5±2 cm) after PI.	33.65	48.89
SEm±	0.78	1.58
CD (P=0.05)	NS	NS
<b>Crop establishment methods</b>		
E <sub>1</sub> - Normal transplanting	40.53	58.26
E <sub>2</sub> - Direct wet seeding on puddled soil	35.09	50.77
E <sub>3</sub> - Direct dry seeding	34.38	49.89
E <sub>4</sub> - Broadcasting on un-puddled soil	30.53	44.43
SEm±	1.14	2.59
CD (P=0.05)	3.39	7.69
<b>Interaction I × E</b>		
SEm±	1.98	4.48
CD (P=0.05)	NS	NS

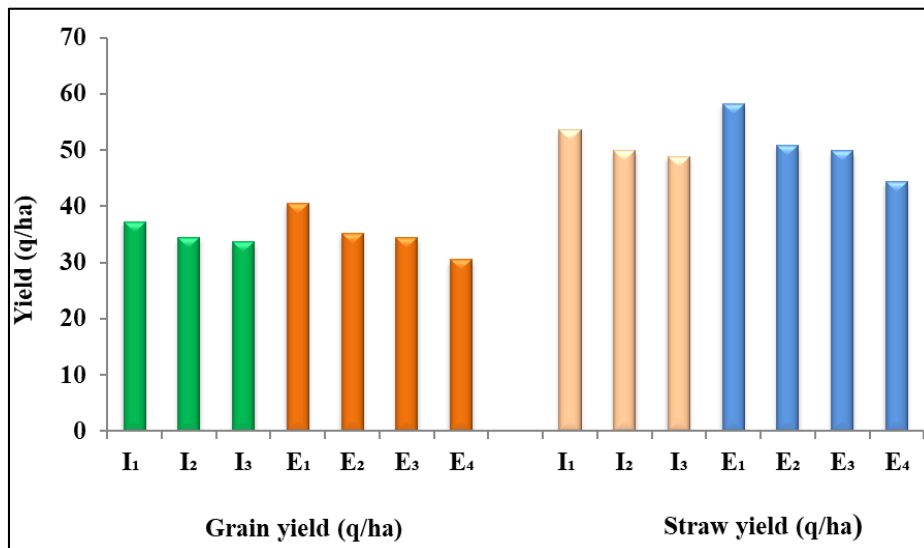


Fig a: Grain yield (q/ha) and Straw yield (q/ha) as affected by different treatments.

Table 2: Water Use Efficiency and water productivity as affected by different treatments

Treatments	Water use efficiency (kg/ha-cm)	Water productivity (₹/m³)
<b>Irrigation management</b>		
I1 - Continuous submergence throughout crop growth.	32.26	3.60
I2 - Saturation maintenance upto PI and (5±2cm) after PI.	35.03	3.96
I3 - Alternate wetting and drying (5 cm irrigation at 3 DADPW) upto PI and (5±2 cm) after PI.	37.90	4.41
SEm±	0.89	0.23
CD (P=0.05)	3.51	NS
<b>Crop establishment methods</b>		
E1- Normal transplanting	44.50	5.19
E2- Direct wet seeding on puddled soil	29.80	3.17
E3- Direct dry seeding	34.92	4.17
E4- Broadcasting on un-puddled soil	31.04	3.45
SEm±	1.18	0.32
CD (P=0.05)	3.51	0.94
<b>Interaction I × E</b>		
SEm±	2.05	0.55
CD (P=0.05)	NS	NS

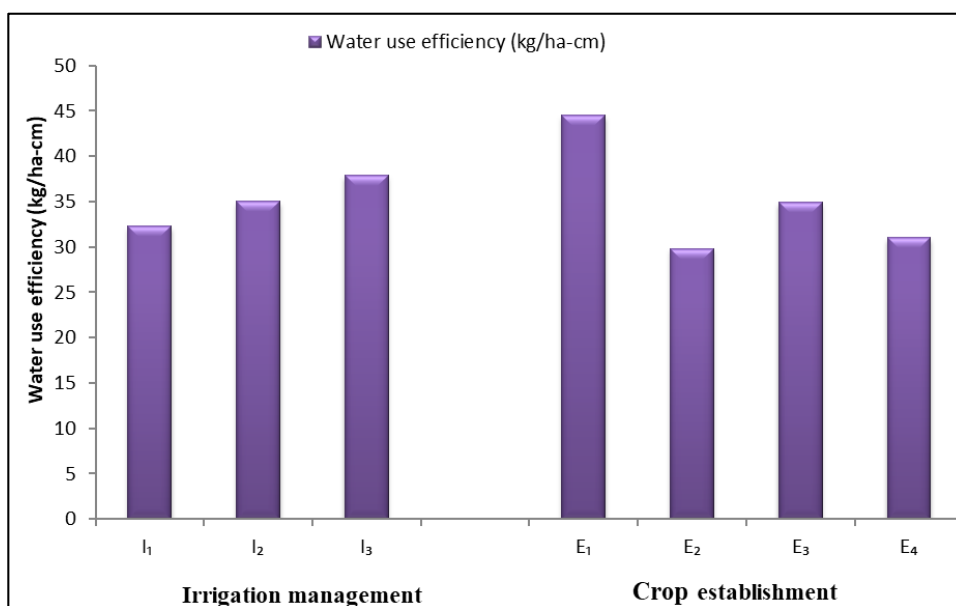


Fig b: Water use efficiency as affected by different treatments

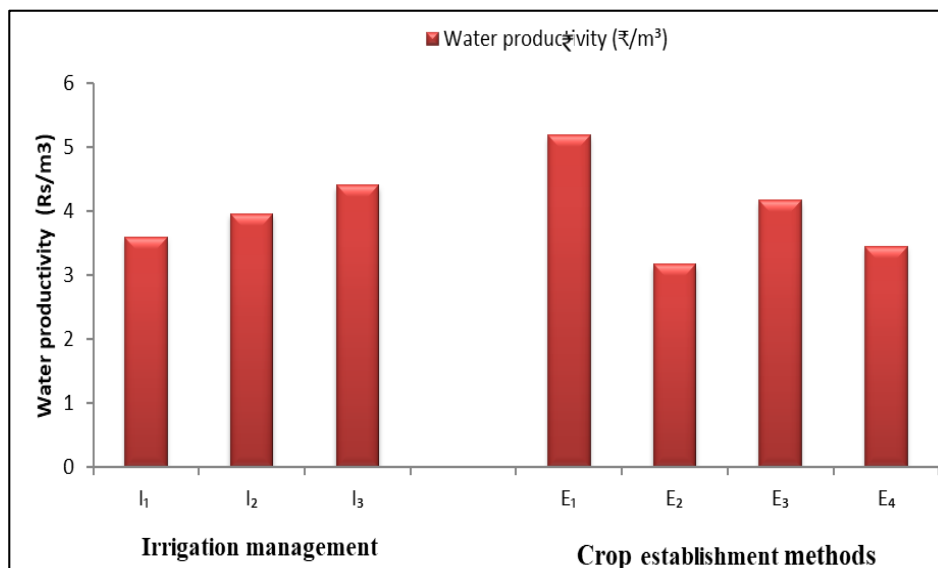


Fig c: Water productivity as affected by different treatments

### Conclusion

From the experiment conducted, it can be concluded that normal transplanting method among all other crop establishment methods in paddy produce significant biological yield but different irrigation managements did not produce any significant impact on biological yield. Similarly, normal transplanting was found superior for economic paddy cultivation due to highest water use efficiency and water productivity. Water use efficiency and water productivity was found significant with alternate wetting and drying up to panicle initiation, over all the irrigation managements.

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