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Influence of drip irrigation levels and varieties on water productivity and microbial population dynamics in direct seeded rice system

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Abstract
A field experiment was conducted at Agricultural and Horticultural research station, Bhavikere, Karnataka in red sandy clay loam soil during *summer*-2020 to study the influence of drip irrigation levels and varieties on water productivity and microbial population dynamics of direct seeded rice. Research was carried out in split plot design consisting of four levels of irrigation in the main plot and four different varieties in sub plot, it was replicated thrice. The experimental results revealed that, higher water productivity of 80.61 kg $ha\text{-}cm^{-1}$ recorded in scheduling of irrigation at 0.75 IW/CPE ratio and among the varieties tested MAS 946-1 recorded higher water productivity of 77.59 kg $ha\text{-}cm^{-1}$. Whereas, with respect to the microbial population studied, scheduling of irrigation at 1.50 IW/CPE ratio recorded higher number of bacterial, fungal and actinomycetes population at harvest in soil (53.09 $cfu \times 10^5$/g of soil, 23.73 $cfu \times 10^4$/g of soil and 10.83 $cfu \times 10^3$/g of soil, respectively) and among the varieties studied higher number of bacterial, fungal and actinomycetes population at harvest in soil (52.74 $cfu \times 10^5$/g of soil, 23.93 $cfu \times 10^4$/g of soil and 10.85 $cfu \times 10^3$/g of soil, respectively) recorded in MAS 946-1 grown plots.

Keywords: Direct seeded rice, IW/CPE, water productivity and microbial population

Introduction

Rice (*Oryza sativa* L.) is the staple food crop of for more than half of the world's population. It is grown in six continents and in more than hundred countries. In Asia, more than two billion people are getting 60-70 per cent of their energy requirement from rice and its derived products (Geethalakshmi *et al.*, 2011) [7]. Human consumption accounts 85 per cent of total production and hence rice deserves a special status among cereals as world's most important wetland crop.

Out of total water available in India, 60 per cent is utilized for rice cultivation. Thus lack of water rather than land may become the principal constraint to increase food output and to keep the world in peace (Sivanappan, 1997) [22]. Efficient utilisation of available water resources is crucial for a country like India, which supports 17 per cent of the global population with only 2.4 per cent of land and 4 per cent of the water resources. The annual food grain requirement of India works out to be 450 m t by the year 2050 and the per capita availability in terms of average utilizable water resources, which was 6008 m^3 in the year 1947 and 1545 m^3 in the year 2013, is expected to dwindle down to 1340 m^3 and 1140 m^3 by the year 2025 and 2050, respectively (Jha, 2013) [12].

Increasing water scarcity, water loving nature of rice cultivation and increasing labour wages triggers the search for such alternative crop establishment methods which can increase water productivity. Direct seeded rice (DSR) is the only viable option to reduce the unproductive water flows.

Drip irrigation can supply water both precisely and uniformly at a high irrigation frequency compared to furrow and sprinkler irrigation, thus potentially increasing yield, reducing subsurface drainage, providing better salinity control and better disease management since only the soil is wetted whereas the leaf surface stays dry (Hanson and May, 2007) [10]. However, there are still many things unclear about the practicability of this irrigation system as to the water use efficiency on rice plant, the yield ability and the production cost.

One of the important sources of maintaining soil fertility is use of biofertilizers. The role of biofertilizers, an alternate low cost input has a prime importance in recent decades and they play a vital role in maintaining long-term soil fertility. Biological nitrogen fixing microorganisms significantly contributed for nitrogen addition to soil while phosphate and potassium helps in solubilizing bound form of phosphorous and potassium in soil. These beneficial microorganisms are known to secrete plant growth promoting substances for improved plant growth and crop yield (Venkatashwarlu and Prasad 2012) [27].

Keeping all these points in view, the paper entitled "Influence of drip irrigation levels and varieties on water productivity and microbial population dynamics in direct seeded rice system." was carried out.

Material and Methods

Location of the experimental site

The experiment was conducted at Agricultural and Horticultural Research Station, Bhavikere which is situated between 75°51` E longitude and 13°42` N with an altitude of 695 meters above the mean sea level and is located in Zone-7 of Karnataka.

Experimental details

The experiment was laid out in split plot design and comprised of two factors for study *viz.,* Main plot treatments: Irrigation schedules comprised *viz.,* I_1: Irrigation at 0.75 IW/CPE ratio, I_2: Irrigation at 1.00 IW/CPE ratio, I_3: Irrigation at 1.25 IW/CPE ratio and I_4: Irrigation at 1.50 IW/CPE ratio. Subplot treatments: Varieties comprised *viz.,* V_1: Local variety, V_2: Jyothi, V_3: MAS 946-1 and V_4: MAS-26. The varietal description given in the table 1. The gross plot size was 4.8 m × 3.0 m and net plot size was 3.6 m × 2.6 m. The spacing given was 30 cm × 10 cm.

Table 1: Description of the varieties used

Varieties	Duration (days)	Average yield (A) Potential yield (P)	Characteristics and special features
Local variety (Vernacular name: *Buddabatta*)	125-130	A: 35-40 q ha^{-1} P: 55-60 q ha^{-1}	Tall, bold grains with red colour, local variety preserved from time immoral and in use with several farmers for DSR under Shikaripura and Soraba taluk of Shivamogga district of Karnataka
Jyothi	120-125	A: 45-50 q ha^{-1} P: 65-70 q ha^{-1}	Semi dwarf, medium bold grains with red colour, resistance to blast disease
MAS-26	125-130	A: 60-65 q ha^{-1} P: 85-90 q ha^{-1}	Semi dwarf, medium slender grains, deep rooted, drought and blast resistance
MAS 946-1	125-130	A: 60-65 q ha^{-1} P: 90-95 q ha^{-1}	Semi dwarf, medium slender grains, deep rooted, drought and blast resistance

Irrigation scheduling

Irrigation was given based on the climatological approach (IW/CPE ratio), where the daily pan evaporation rate was recorded from the standard USWB class A open pan evaporimeter. To apply 5 cm depth of irrigation the cumulative pan evaporation (CPE) has to reach 33.33, 40, 50 and 66.66 mm for 1.50, 1.25, 1.00 and 0.75 IW/CPE ratios, respectively and the irrigation was given through the drip irrigation system. If there is any effective rainfall received it has been deducted from the pre fixed depth of irrigation and waited till CPE reaches the pre fixed depth. By multiplying the depth of irrigation and area of the plot, the volume of water required for each plot was calculated. Where initial 5 cm depth of irrigation was commonly given to all the plots for uniform germination and then the subsequent irrigations scheduled as per the treatment details. The daily evaporation data collected from USWB class A pan evaporimeter (*summer* 2020) is furnished in the Table 2.

Drip irrigation system which includes pump, filter units, fertigation tank, ventury, main line and sub line for each replication and a lateral for each plot. The water source was bore well. Water was pumped through 5 HP motor and it was conveyed to the main field using mains after filtering through sand and screen filter which was in turn connected with sub mains. Further, sub mains were laid perpendicular to replications of the experiment; the laterals were attached to the sub main at 60 cm interval in such a way that the laterals were parallel to the rows of direct seeded rice. The water was made to discharge through inline emitters @ 2 lph @ 2 kg cm^{-2} pressure.

Volume of water required (l) = Depth of irrigation × area of the plot

Where

1 ha cm=1,00,000 litres

Time of operation of drip system to deliver required volume of water per plot was computed based on the formula.

$$\text{Time of application} = \frac{\text{Volume of water required (l)}}{\text{Emitter discharge (l ha}^{-1}\text{)} \times \text{No. of emitters plot}^{-1}}$$

Application of the microbial consortia along g with Manure and fertilizer application

At the time of FYM application, recommended dose of FYM (10 t ha^{-1}) was mixed with the liquid plant growth promoting rhizomicrobial consortia (*Azospirillum* + PSB + KSB) at 625 ml ha^{-1} and it was applied two weeks before sowing for all the treatments.

With respect to the recommended doses of fertilizers, 50 per cent N and 100 per cent P and K as basal and remaining 50 per cent nitrogen was top dressed at the rate of 25 per cent each at 30 and 60 days after sowing. The sources of nutrients is through urea (46:0:0), Di ammonium phosphate (18:46:0) and murate of potash (0:0:60).

Table 2: Daily evaporation and rainfall data during the crop period *summer* -2020

Date	Evaporation (mm)	Rainfall (mm)	Date	Evaporation (mm)	Rainfall (mm)	Date	Evaporation (mm)	Rainfall (mm)
16-Feb	6.3	-	31-Mar	6.4	-	14-May	4.7	8.6
17-Feb	5.9	-	01-Apr	7.2	-	15-May	5	-
18-Feb	6	-	02-Apr	7	-	16-May	4.9	-
19-Feb	6.3	-	03-Apr	7.9	-	17-May	4.8	-
20-Feb	6.1	-	04-Apr	7.8	-	18-May	3.2	25
21-Feb	6.3	-	05-Apr	8	-	19-May	5.6	-
22-Feb	6.5	-	06-Apr	7	-	20-May	4.6	-
23-Feb	6	-	07-Apr	6.2	-	21-May	4.6	-
24-Feb	6.2	-	08-Apr	6.7	-	22-May	4.8	-
25-Feb	5.6	-	09-Apr	6.9	-	23-May	5	-
26-Feb	5.7	-	10-Apr	7.2	-	24-May	4.7	-
27-Feb	6	-	11-Apr	7	-	25-May	5.3	-
28-Feb	6.1	-	12-Apr	7.5	-	26-May	4.9	3.8
29-Feb	6.4	-	13-Apr	8	-	27-May	6.7	-
01-Mar	5.9	-	14-Apr	9	-	28-May	7.8	-
02-Mar	3.9	-	15-Apr	6.9	-	29-May	4.7	-
03-Mar	4.7	-	16-Apr	6.2	-	30-May	5.2	-
04-Mar	4.9	-	17-Apr	6	-	31-May	5	13.6
05-Mar	4.9	-	18-Apr	6.1	-	01-Jun	5.9	-
06-Mar	5.3	-	19-Apr	5.9	-	02-Jun	6.8	-
07-Mar	5.6	-	20-Apr	7.8	-	03-Jun	5.2	-
08-Mar	5.9	-	21-Apr	6.5	-	04-Jun	7.8	-
09-Mar	6.7	-	22-Apr	5.9	4	05-Jun	2.7	-
10-Mar	6	-	23-Apr	5.6	-	06-Jun	3.2	-
11-Mar	5.8	-	24-Apr	5.6	-	07-Jun	5.6	-
12-Mar	6.3	-	25-Apr	6.2	-	08-Jun	4.7	-
13-Mar	6	-	26-Apr	6.2	-	09-Jun	5	-
14-Mar	6.2	-	27-Apr	5.7	-	10-Jun	6	-
15-Mar	6.1	-	28-Apr	7.4	-	11-Jun	6	-
16-Mar	5.6	-	29-Apr	5.9	-	12-Jun	2	-
17-Mar	7	-	30-Apr	6.2	-	13-Jun	1.8	-
18-Mar	7	-	01-May	6.8	-	14-Jun	1.6	-
19-Mar	7.2	-	02-May	7	-	15-Jun	2.3	-
20-Mar	7.4	-	03-May	4.3	8.8	16-Jun	2.3	-
21-Mar	7.4	-	04-May	7.9	-	17-Jun	2	-
22-Mar	7.8	-	05-May	4.2	16.6	18-Jun	1.5	-
23-Mar	7.5	-	06-May	6.6	-	19-Jun	4	-
24-Mar	6.7	-	07-May	7.2	-	20-Jun	5.1	-
25-Mar	6.8	-	08-May	4.4	8.4	21-Jun	4	-
26-Mar	7.8	-	09-May	6.3	-	22-Jun	3.8	-
27-Mar	6	-	10-May	6.7	-			
28-Mar	6.5	-	11-May	4.6	0.7			
29-Mar	6.3	-	12-May	4.8	3.2			
30-Mar	6.7	-	13-May	4.9	-			

Calculation of water use efficiency (WUE)

Water use efficiency was worked out from the yield of direct seeded rice and the amount of water used (Viets, 1972) [28] and expressed in kg ha-cm^{-1}.

$$\text{WUE} = \frac{\text{Grain yield (kg ha}^{-1}\text{)}}{\text{Quantity of total water applied (cm)}}$$

Analysis of biological properties of soil

Total microbial count in soil

Dilution and plate count technique was used for enumerating the total bacteria, fungi and actinomycetes where 10 g soil (soil sample obtained from individual gross plot at 60, 90 and at harvest) was suspended in 100 ml water to obtain 10^1 dilutions. One ml of this suspension was added to 9 ml water to get a dilution of 10^2. Similarly, the dilution was continued until 10^6 dilutions were obtained. From 10^5 dilution 1ml was added to sterile Petri plate for enumeration of bacteria and 1ml from 10^4 and 10^3 dilutions for fungi and actinomycetes, respectively.

Then 15 ml of the appropriate media (Table 3) was added to each plate and rotated in the clockwise and anticlockwise direction. After solidification, the plates were incubated in an inverted position at room temperature. After the incubation period, the colonies were counted assuming that each viable cell will give rise to a single colony. Finally, the number of colonies (CFU) in 1 g of soil was calculated by using the following formula as described by Skinner *et al*. (1952) [23].

$$\text{No. of colonies per gram of soil (CFU)} = \frac{\text{No. of colonies} \times \text{Dilution factor}}{\text{ml taken for dilution} \times \text{Weight of soil (g)}}$$

Table 3: Different growth media and their composition used for microbial counts in soil

Media	Bacteria	Fungi	Actinomycetes
	Nutrient agar (NA)	Martin rose Bengal agar media (MRBA)	Kuster's agar (KA)
Beef extract (g)	3.0	-	-
Peptone (g)	5.0	5.0	-
Glucose (g)	5.0	-	-
NaCl (g)	5.0	-	2.0
Agar (g)	20.0	20.0	20.0
Dextrose (g)	-	10.0	2.0
KH_2PO_4 (g)	-	1.0	0.02
$MgSO_47H_2O$ (g)	-	0.5	0.05
Rose Bengal (g)	-	0.3	-
Glycerol (g)	-	-	10.0
Casein (g)	-	-	0.3
KNO_3 (g)	-	-	2.0
$CaCO_3$ (g)	-	-	0.02
$FeSO_4$ (g)	-	-	0.1
Water (ml)	1000.0	1000.0	1000.0
pH	7.0	6.0	7.1-7.2

Results and Discussion

Grain yield of direct seeded rice as influenced by the levels of irrigation schedules and varieties

Grain yield of direct seeded rice as influenced by scheduling of irrigation and varieties are presented in the Table 4.

Grain yield was significantly influenced by irrigation schedules. Results indicated that grain yield increased with the increase in levels of irrigation schedules. Grain yield was found significantly higher in scheduling of irrigation at 1.50 IW/CPE ratio (5569 kg ha^{-1}) and it was on par with 1.25 IW/CPE ratio (5268 kg ha^{-1}). Scheduling of irrigation at 0.75 IW/CPE ratio recorded significantly lower grain yield (4143 kg ha^{-}).

The higher grain yield was recorded with higher levels of the irrigation regimes might be due to the higher growth and yield attributes as well conducive situation for efficient water and nutrients uptake which boost their growth and yield attributes through supply of more photosynthates towards the reproductive sink. The similar results of reduced levels of irrigation on reduction in grain yield are reported by Akinbile, 2011 [1], Govindan and Grace, 2012 [8], Gururaj, 2013 [9], Nagaraju *et al.* 2014 [16], Ramanamurthy *et al.*, 2017 [19], Keerthi *et al.*, 2018 [14], Padmaja and Mallareddy, 2019 [17].

Varieties of rice significantly influenced the grain yield. Significantly higher grain yield was recorded in MAS 946-1 variety (5743 kg ha^{-1}) and it was on par with MAS-26 (5614 kg ha^{-1}). Significantly lower grain yield (3463 kg ha^{-1}) was recorded in local variety.

Yield increase in the varieties was mainly due to the potential genetic makeup the variety helps for the increased uptake and utilization of the applied nutrients effectively resulting in enhanced growth and yield attributes promotes the increased photosynthetic efficiency of the variety leading to greater dry matter production and translocation to sink. Results which shows the significant variation ion grain yield among the varieties reported by Singh and Sridevi (2006) [21], Sridhara (2008) [24], Veeresh *et al.* (2011) [26], Ramachandra *et al.* (2015) [18], Sritharan *et al.* (2015) [25], Yadav *et al.* (2017) [29], Dawadi and Chaudary (2018) [5] and Joseph *et al.* (2019) [13].

Water use efficiency (kg ha-cm^{-1}) of direct seeded rice as influenced by irrigation schedules and varieties

The data on irrigation water used, total water used and water use efficiency under drip irrigation for the given study are presented in the Table 5.

The irrigation water applied was 908, 758, 605 and 422 mm for irrigation scheduling at 1.50, 1.25, 1.00 and 0.75 IW/CPE ratio, respectively.

With respect to the varieties, all the varieties consumed 673.25 mm of irrigation water applied.

The total water applied was 1000, 850, 697 and 514 mm for irrigation scheduling at 1.50, 1.25, 1.00 and 0.75 IW/CPE ratio, respectively.

With respect to the varieties, all the varieties consumed total irrigation water of 765.25 mm.

Among the schedules of irrigation, scheduling of irrigation at 0.75 IW/CPE ratio recorded significantly higher water use efficiency (80.61 kg ha-cm^{-1}) and significantly lower water use efficiency (55.69 kg ha-cm^{-1}) was recorded in irrigation scheduling at 1.50 IW/CPE ratio. The results revealed that highest water use efficiency at the reduced levels of irrigation. This is mainly due to the at reduced levels of irrigation it require very less amount of irrigation water for producing unit amount of dry matter particularly grain yield. The results are in accordance with the (Maheswari *et al.*, 2007; Shekara *et al.*, 2010; Anusha *et al.*, 2015 and Padmaja and Mallareddy, 2019) [15, 20, 4, 17].

Among the varieties of rice, significantly higher water use efficiency was recorded in MAS 946-1 variety (77.59 kg ha-cm^{-1}) and it was at par with the MAS-26 (75.85 kg ha-cm^{-1}). Significantly lower water use efficiency (46.74 kg ha-cm^{-1}) was recorded in local variety of rice. The highest water use efficiency with MAS 946-1 and MAS-26 compared to other two varieties due to MAS 946-1 and MAS-26 with the same levels of applied irrigation water produced significantly higher grain yield. The results are in accordance with the Dinesh kumar *et al.* (2013) [6], Anamika *et al.* (2014) [2] and Nagaraju *et al.* (2014a) [16].

Non significant interaction effect on water use efficiency due to scheduling of irrigation and varieties was noticed. Where, the highest water use efficiency recorded in scheduling of irrigation at 0.75 IW/CPE ratio with MAS 946-1 variety (94.88 kg ha-cm^{-1}) and lowest among the interaction was recorded in 1.50 IW/CPE with local variety (40.22 kg ha-cm^{-1}).

Microbial population of soil at different growth stages

Bacterial population of soil at different growth stages

The data on bacterial population of soil at 60, 90 DAS and at harvest in direct seeded rice as influenced by irrigation schedules and rice varieties is represented in the Table 6.

Bacterial population was significantly influenced by irrigation schedules. Results indicated that bacterial population increased with the increase in levels of irrigation schedules. Bacterial population at 60, 90 DAS and at harvest was found significantly higher in scheduling of irrigation at 1.50 IW/CPE ratio (64.30, 70.92 and 53.09 cfu×10^5/g of soil, respectively) and it was on par with 1.25 IW/CPE ratio (61.91, 68.32 and 51.44 cfu×10^5/g of soil, respectively). Scheduling of irrigation at 0.75 IW/CPE ratio recorded significantly lower bacterial population (49.53, 54.98 and 42.34 cfu×10^5/g of soil, respectively).

Varieties of rice significantly influenced the bacterial population in soil. Where, significantly higher bacterial population were recorded at 60, 90 DAS and at harvest of MAS 946-1 variety plots (63.58, 70.14 and 52.74 cfu×10^5/g of soil, respectively) and it was on par with MAS-26 plots (62.30, 68.74 and 51.49 cfu×10^5/g of soil, respectively). Significantly lower bacterial population (47.36, 52.69 and 40.94 cfu×10^5/g of soil, respectively) was recorded in local variety plots.

Bacterial population observed non significant difference in the interaction of irrigation schedules and rice varieties. Wherein, scheduling irrigation at 1.50 IW/CPE ratio with MAS 946-1 variety plots recorded highest bacterial population at 60, 90 DAS and at harvest (71.66, 78.98 and 58.50 cfu×10^5/g of soil, respectively) and 0.75 IW/CPE ratio with local variety plots recorded lower bacterial population (43.53, 48.45 and 37.85 cfu×10^5/g of soil, respectively).

Fungal population of soil at different growth stages

The data on fungal population of soil at 60, 90 DAS and at harvest as influenced by effect of irrigation schedules and varieties in direct seeded rice is represented in the Table 7.

Among the irrigation schedules, scheduling of irrigation at 1.50 IW/CPE ratio recorded significantly higher fungal population at 60, 90 DAS and at harvest (28.80, 31.75 and 23.73 cfu×10^4/g of soil, respectively) and it was on par with 1.25 IW/CPE ratio (26.99, 29.77 and 22.38 cfu×10^4/g of soil, respectively). While, significantly lower fungal population (19.08, 21.18 and 16.30 cfu×10^4/g of soil, respectively) was recorded in 0.75 IW/CPE ratio.

With respect to the varieties, MAS 946-1 plots recorded significantly higher fungal population at 60, 90 DAS and at harvest (28.87, 31.84 and 23.93 cfu×10^4/g of soil, respectively) and it was on par with MAS-26 plots (28.01, 30.90 and 23.13 cfu×10^4/g of soil, respectively). Significantly lower fungal population (16.17, 17.99 and 13.98 cfu×10^4/g of soil, respectively) local variety plots.

The interaction of irrigation schedules and varieties on fungal population recorded non significant difference. However, highest fungal population at 60, 90 DAS and at harvest (34.79, 38.34 and 28.40 cfu×10^4/g of soil, respectively) was recorded in 1.50 IW/CPE ratio with MAS 946-1 and the lowest was noticed in scheduling irrigation at 0.75 IW/CPE ratio with local variety plots (15.07, 16.77 and 13.10 cfu×10^4/g of soil, respectively).

Actinomycetes population of soil at different growth stages

The data on actinomycetes population of soil at 60, 90 DAS and at harvest in direct seeded rice as influenced by irrigation schedules and rice varieties is represented in the Table 8.

Actinomycetes population was significantly influenced by irrigation schedules. Results indicated that actinomycetes population increased with the increase in levels of irrigation schedules. Actinomycetes population at 60, 90 DAS and at harvest was found significantly higher in scheduling of irrigation at 1.50 IW/CPE ratio (13.12, 14.47 and 10.83 cfu×10^3/g of soil, respectively) and it was on par with 1.25 IW/CPE ratio (12.47, 13.76 and 10.35 cfu×10^3/g of soil, respectively). Scheduling of irrigation at 0.75 IW/CPE ratio recorded significantly lower actinomycetes population (9.68, 10.75 and 8.28 cfu×10^3/g of soil, respectively).

Varieties of rice significantly influenced the actinomycetes population in soil. Where, significantly higher actinomycetes population were recorded at 60, 90 DAS and at harvest of MAS 946-1 variety plots (13.09, 14.43 and 10.85 cfu×10^3/g of soil, respectively) and it was on par with MAS-26 plots (12.71, 14.02 and 10.50 cfu×10^3/g of soil, respectively). Significantly lower actinomycetes population (8.62, 9.59 and 7.45 cfu×10^3/g of soil, respectively) was recorded in local variety plots.

Actinomycetes population observed non significant difference in the interaction of irrigation schedules and rice varieties. Wherein, scheduling irrigation at 1.50 IW/CPE ratio with MAS 946-1 variety plots recorded highest actinomycetes population at 60, 90 DAS and at harvest (15.07, 16.61 and 12.30 cfu×10^3/g of soil, respectively) and 0.75 IW/CPE ratio with local variety plots recorded lower actinomycetes population (8.05, 8.96 and 7.00 cfu×10^3/g of soil, respectively).

The increase in microbial population with the increased levels of irrigation due to the availability of aerobic environment with higher levels of irrigation makes the favourable environment for soil habituating microbes (Anita *et al*., 2017) [3]. The increased microbial population with the improved varieties over the local variety due the production good root mass enhances the production of growth promoting substances and soil organic carbon. Since, the organic carbon serve as a food for soil fauna and flora and soil organic matter play an important role in the food web by controlling the number and types of soil inhabitants. The results are in accordance with the findings of the Hanuman prasad *et al*. (2014) [11].

Table 4: Grain yield of direct seeded rice as influenced by irrigation schedules and varieties

Grain yield (kg ha^{-1})					
	I_1	**I_2**	**I_3**	**I_4**	**Mean**
V_1	2962^{i}	3214^{hi}	3655^{gh}	4022^{fg}	3463
V_2	3976^{fg}	4429^{ef}	5117^{bcd}	5488^{b}	4753
V_3	4877^{cde}	5420^{b}	6201^{a}	6475^{a}	5743
V_4	4758^{de}	5309^{bc}	6099^{a}	6289^{a}	5614
Mean	4143	4593	5268	5569	
		S.Em.±		CD (P=0.05)	
Main plot (I)		109		376	
Sub plot (V)		76		220	
Interaction (IXV)		152		NS	

Main plot: Irrigation scheduling (I)
I_1: Irrigation at 0.75 IW/CPE ratio
I_2: Irrigation at 1.00 IW/CPE ratio
I_3: Irrigation at 1.25 IW/CPE ratio
I_4: Irrigation at 1.50 IW/CPE ratio

Sub plot: Varieties (V)
V_1: Local variety
V_2: Jyothi
V_3: MAS 946-1
V_4: MAS-26

Note: Values followed by different alphabets significantly differ from each other

Table 5: Total water used and water use efficiency (kg ha-cm^{-1}) of direct seeded rice as influenced by irrigation schedules and varieties

	Irrigation water applied (mm)					**Total water applied (I_R + E_R)**					**Water use efficiency (kg ha-cm^{-1})**					**Number if irrigations given**				
	I_1	**I_2**	**I_3**	**I_4**	**Mean**	**I_1**	**I_2**	**I_3**	**I_4**	**Mean**	**I_1**	**I_2**	**I_3**	**I_4**	**Mean**	**I_1**	**I_2**	**I_3**	**I_4**	**Mean**
V_1	422.00	605.00	758.00	908.00	673.25	514.00	697.00	850.00	1000.00	765.25	57.63	46.11	43.00	40.22	46.74	10.00	14.00	17.00	20.00	15.25
V_2	422.00	605.00	758.00	908.00	673.25	514.00	697.00	850.00	1000.00	765.25	77.35	63.54	60.20	54.88	63.99	10.00	14.00	17.00	20.00	15.25
V_3	422.00	605.00	758.00	908.00	673.25	514.00	697.00	850.00	1000.00	765.25	94.88	77.76	72.95	64.75	77.59	10.00	14.00	17.00	20.00	15.25
V_4	422.00	605.00	758.00	908.00	673.25	514.00	697.00	850.00	1000.00	765.25	92.57	76.17	71.75	62.89	75.85	10.00	14.00	17.00	20.00	15.25
Mean	422.00	605.00	758.00	908.00		514.00	697.00	850.00	1000.00		80.61	65.90	61.98	55.69		10.00	14.00	17.00	20.00	

	S.Em±	C.D.(P=0.05)	S.Em±	C.D.(P=0.05)	S.Em±	C.D.(P=0.05)	S.Em±	C.D.(P=0.05)
Main plot(I)	NA	NA	NA	NA	1.32	4.56	NA	NA
Sub plot (V)	NA	NA	NA	NA	1.16	3.37	NA	NA
Interaction (IXV)	NA	NA	NA	NA	2.31	NS	NA	NA

Main plot: Irrigation scheduling **(I)**
I_1: Irrigation at 0.75 IW/CPE ratio
I_2: Irrigation at 1.00 IW/CPE ratio
I_3: Irrigation at 1.25 IW/CPE ratio
I_4: Irrigation at 1.50 IW/CPE ratio
*NA-Not analysed

Sub plot: Varieties **(V)**
V_1: Local variety
V_2: Jyothi
V_3: MAS 946-1
V_4: MAS-26

Table 6: Bacterial population (cfu×10^5/g of soil) of soil at different growth stages of direct seeded rice as influenced by irrigation schedules and varieties

	60 DAS					**90 DAS**					**At harvest**				
	I_1	**I_2**	**I_3**	**I_4**	**Mean**	**I_1**	**I_2**	**I_3**	**I_4**	**Mean**	**I_1**	**I_2**	**I_3**	**I_4**	**Mean**
V_1	43.53	46.40	49.22	50.28	47.36	48.45	51.63	54.78	55.90	52.69	37.85	40.21	42.50	43.20	40.94
V_2	48.63	56.31	63.00	64.89	58.21	54.04	62.28	69.31	71.36	64.24	41.60	47.36	52.15	53.45	48.64
V_3	53.52	60.77	68.39	71.66	63.58	59.40	67.02	75.17	78.98	70.14	45.55	50.81	56.10	58.50	52.74
V_4	52.42	59.39	67.05	70.36	62.30	58.05	65.42	74.03	77.45	68.74	44.35	49.41	55.00	57.20	51.49
Mean	49.53	55.72	61.91	64.30		54.98	61.59	68.32	70.92		42.34	46.95	51.44	53.09	

	S.Em.±	CD (P=0.05)	S.Em.±	CD (P=0.05)	S.Em.±	CD (P=0.05)
Main plot (I)	1.31	4.55	1.45	5.03	1.11	3.83
Sub plot (V)	0.92	2.69	1.02	2.98	0.78	2.29
Interaction (IXV)	1.85	NS	2.05	NS	1.57	NS

Main plot: Irrigation scheduling **(I)**
I_1: Irrigation at 0.75 IW/CPE ratio
I_2: Irrigation at 1.00 IW/CPE ratio
I_3: Irrigation at 1.25 IW/CPE ratio
I_4: Irrigation at 1.50 IW/CPE ratio

Sub plot: Varieties **(V)**
V_1: Local variety
V_2: Jyothi
V_3: MAS 946-1
V_4: MAS-26

Table 7: Fungal population (cfu×10^4/g of soil) of soil at different growth stages of direct seeded rice as influenced by irrigation schedules and varieties

	60 DAS					90 DAS					At harvest				
	I_1	I_2	I_3	I_4	Mean	I_1	I_2	I_3	I_4	Mean	I_1	I_2	I_3	I_4	Mean
V_1	15.07	15.35	16.68	17.58	16.17	16.77	17.08	18.56	19.54	17.99	13.10	13.30	14.40	15.10	13.98
V_2	18.70	24.26	28.03	29.14	25.03	20.78	26.83	30.83	32.04	27.62	16.00	20.40	23.20	24.00	20.90
V_3	21.97	26.91	31.82	34.79	28.87	24.38	29.68	34.97	38.34	31.84	18.70	22.50	26.10	28.40	23.93
V_4	20.57	26.32	31.45	33.70	28.01	22.78	29.00	34.73	37.10	30.90	17.40	21.90	25.80	27.40	23.13
Mean	19.08	23.21	26.99	28.80		21.18	25.64	29.77	31.75		16.30	19.53	22.38	23.73	

	60 DAS S.Em.±	60 DAS CD (P=0.05)	90 DAS S.Em.±	90 DAS CD (P=0.05)	At harvest S.Em.±	At harvest CD (P=0.05)
Main plot (I)	0.53	1.84	0.59	2.04	0.45	1.54
Sub plot (V)	0.36	1.07	0.40	1.18	0.31	0.90
Interaction (IXV)	0.73	NS	0.81	NS	0.62	NS

Main plot: Irrigation scheduling **(I)**
I_1: Irrigation at 0.75 IW/CPE ratio
I_2: Irrigation at 1.00 IW/CPE ratio
I_3: Irrigation at 1.25 IW/CPE ratio
I_4: Irrigation at 1.50 IW/CPE ratio

Sub plot: Varieties **(V)**
V_1: Local variety
V_2: Jyothi
V_3: MAS 946-1
V_4: MAS-26

Table 8: Actinomycetes population (cfu×10^3/g of soil) of soil at different growth stages of direct seeded rice as influenced by irrigation schedules and varieties

	60 DAS					90 DAS					At harvest				
	I_1	I_2	I_3	I_4	Mean	I_1	I_2	I_3	I_4	Mean	I_1	I_2	I_3	I_4	Mean
V_1	8.05	8.31	8.80	9.31	8.62	8.96	9.24	9.80	10.35	9.59	7.00	7.20	7.60	8.00	7.45
V_2	9.70	11.30	12.80	13.23	11.76	10.78	12.49	14.09	14.55	12.98	8.30	9.50	10.60	10.90	9.83
V_3	10.69	12.20	14.38	15.07	13.09	11.87	13.45	15.81	16.61	14.43	9.10	10.20	11.80	12.30	10.85
V_4	10.28	11.78	13.90	14.88	12.71	11.39	12.98	15.34	16.38	14.02	8.70	9.80	11.40	12.10	10.50
Mean	9.68	10.90	12.47	13.12		10.75	12.04	13.76	14.47		8.28	9.18	10.35	10.83	

	60 DAS S.Em.±	60 DAS CD (P=0.05)	90 DAS S.Em.±	90 DAS CD (P=0.05)	At harvest S.Em.±	At harvest CD (P=0.05)
Main plot (I)	0.26	0.88	0.28	0.98	0.21	0.74
Sub plot (V)	0.18	0.52	0.20	0.57	0.15	0.44
Interaction (IXV)	0.36	NS	0.39	NS	0.30	NS

Main plot: Irrigation scheduling **(I)**
I_1: Irrigation at 0.75 IW/CPE ratio
I_2: Irrigation at 1.00 IW/CPE ratio
I_3: Irrigation at 1.25 IW/CPE ratio
I_4: Irrigation at 1.50 IW/CPE ratio

Sub plot: Varieties **(V)**
V_1: Local variety
V_2: Jyothi
V_3: MAS 946-1
V_4: MAS-26

Conclusion

The study revealed that plots which received the higher levels of irrigation have recorded highest number of microbial population and lowest water productivity and vice versa. Among the varieties used for direct seeded rice, highest water productivity and higher microbial population was recorded in MAS 946-1 plots and lowest was found in the local variety of rice.

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