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Full Research Article

Optimization of Water and Nutrient Requirement through Drip Fertigation in Aerobic Rice

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Abstract

A field experiment was conducted during *Kharif* 2012 at Zonal Agricultural Research Station, Bengaluruin red sandy loam soil (pH-6.9; OC-0.6%) with medium available nitrogen (348 kg ha^{-1}), phosphorous (36.13 kg ha^{-1}) and potassium (244 kg ha^{-1}) to optimize water and nutrient requirement of aerobic rice (*Oryza sativa* L.) through drip fertigation. The experiment was laid out in Randomized Complete Block Design (RCBD) with 15 treatments. The variety used was MAS 946-1. Drip fertigation significantly influenced the growth, yield, water productivity and nutrient use efficiency (NUE) in aerobic rice. The results revealed that drip fertigation at 1.5 PE up to maturity with 100% RDF through water soluble fertilizers (WSF) registered higher water use (706 mm) and significantly highest water productivity (78.1 kg ha-cm^{-1}) by recording higher grain (6598 kg ha^{-1}) and straw yield (11084 kg ha^{-1}) over surface irrigation with soil application of fertilizers (3467 and 5995 kg ha^{-1}, respectively). Same treatment also noticed higher number of tillers $hill^{-1}$ (48.13) and higher dry matter production (118.40 g $hill^{-1}$) by saving 45% of irrigation wateras that of surface irrigation. Dripfertigation at 1.5 PE up to maturity with 50% RDF through WSF has recorded higher nitrogen (98.3 kg kg^{-1}), phosphorus (196.7 kg kg^{-1}) and potassium (196.7 kg kg^{-1}) use efficiency. However, increased nutrient use efficiency (NUE) was observed with reduced nutrient levels.

1. Introduction

Rice is most important staple food crop in Asia and it occupies the enviable prime place among the food crops after wheat. Human consumption accounts 85% of total production for rice and it deserves a special status among cereals as world's most important wetland crop. This global grain provides 20% of world's dietary energy supply, while wheat and maize supplies 19 and 5%, respectively (Anon, 2013).

Water and fertilizer are the two basic inputs in irrigated agriculture, while the former is less costly than the later at present. The time is not too far off when water becomes scarce and costlier due to increased industrialisation and intensive agriculture resulting from the increasing food and fibre needs of the burgeoning population round the globe. Efficient utilisation of available water resources is crucial for a country like India, which shares 17% of the global population with only 2.4% of land and 4% of the water resources.

Over the past decade, we have witnessed a growing scarcity and competition for water around the world. As the water demand for domestic, municipal, industrial and environmental purposes rises in the near future, the water availability for agriculture sector gets affected. The estimated water availability for agriculture which is 83.3% of total water used today, will shrink to 71.6% in 2025 and to 64.6% in 2050 (Yadav, 2002).

Fertilizer application in wetland rice farming is currently done manually through the soil application in split doses. The technique employed is imprecise and causes problems such as fluctuating nutrient supply and uneven fertilizer spread. It is labour intensive and makes use of expensive fertilizers. This leads to various losses of nutrients under submerged cultivation. Besides loss of water and fertilizers through seepage and percolation, impounding water in paddy fields has an important environmental impact by contributing to global warming through considerable emission of methane.

With this background, an investigation was carried out to optimize the water and nutrient requirement of aerobic rice through drip fertigation.

2. Materials and Methods

The field experiment was conducted at the Zonal Agricultural Research Station, University of Agricultural Sciences, GKVK, Bengaluru and Karnataka during *Kharif* 2012. The soil was redsandy clay loam in nature and near neutral in reaction (pH: 6.9) and organic carbon (OC) content was high (0.60%). The soil test results ofthe experimental site reveal that soil is medium in nitrogen, phosphorus andpotassium, respectively. The average annual rainfall of site is around 926 mm.The field experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Treatment details are as follows; T_1: Surface irrigation with soil application of RDF*, T_2: Drip irrigation (1.5 PE**) with soil application of 100% RDF, T_3: Drip irrigation (1.0+1.5 PE) with soil application of 100% RDF, T_4: Drip fertigation (1.5 PE) with 100% RDF through NF#, T_5: Drip fertigation (1.5 PE) with 75% RDF through NF, T_6: Drip fertigation (1.5 PE) with 50% RDF through NF, T_7: Drip fertigation (1.0+1.5 PE) with 100% RDF through NF, T_8: Drip fertigation (1.0+1.5 PE) with 75% RDF through NF, T_9: Drip fertigation (1.0+1.5 PE) with 50% RDF through NF, T_{10}: Drip fertigation (1.5) with 100% RDF through WSF##, T_{11}: Drip fertigation (1.5) with 75% RDF through WSF, T_{12}: Drip fertigation (1.5) with 50% RDF through WSF, T_{13}: Drip fertigation (1.0+1.5 PE) with 100% RDF through WSF, T_{14}: Drip fertigation (1.0+1.5 PE) with 75% RDF through WSF, T_{15}: Drip fertigation (1.0+1.5 PE) with 50% RDF through WSF.

2.1. Irrigation and fertilizer application

The irrigation was given through PVC pipe after filtering throughthe screen filter by 7.5 HP motor from the bore well. Thepressure maintained in the system was 1.2 kg cm^{-2}. From thesub main, in-line laterals of 16 mm were laid at a spacing of 0.5 m with 4 lph discharge rate emitters positioned at a distance of 40 cm. Drip irrigation was scheduled based on the open panevaporation as per the treatment requirement after subtractingeffective rainfall for that period. However, surface irrigation was scheduled based on recommended package of practices.

At the time of sowing, FYM was applied to all the treatments at the rate of 10 t ha^{-1}. Fertilizers were applied as per thetreatment details. The soil application was done as per therecommendation. Out of total nutrients, 50% N and theentire dose of P_2O_5 and K_2O were applied as basal and remaining 50% N in two equal splits at 30 and 60 days after sowing (DAS), respectively. However, drip fertigation was given in eight equal splits ateight days interval as per treatment requirement. The fertilizers used for fertigation are Urea, DAP and MOP .The fertilizer recommendation for the crop is 100:50:50 kg NPK ha^{-1}.

The direct sowing was done at 5 cm depth with 25×25 cm^2 spacing. The experiment was maintained as per the standard package of practice of aerobic rice cultivation (Anon, 2007). To overcome border effect observations were made on middleplants in the row. The observations were recorded inexperiments on five random plants at centre of the row forgrowth and yield attributing characters. Numbers of tillers were noted by counting from the sampling unit and was expressed on tillers $hill^{-1}$. Five hills were selected for recording total dry matter production by aerobic rice. These plants were then air dried and further dried in a hot air oven at 62 °C till constant weight was obtained. Dry weight was recorded and was expressed on grams $hill^{-1}$ basis. Crop was harvested at maturity and harvested plants were dried for 3-4 days to bring down moisture content to around 14%. After threshing, seeds were cleaned, sun dried and their weight was recorded. Separated straw was also weighed and both grain and straw yields in kg $plot^{-1}$ were converted to kg ha^{-1}. Irrigation water given was recorded based on pan evaporation values and discharge capacity of emitters. Effective rainfall for the cropping period is summed up with irrigation water applied to get total water used for crop production. Water productivity of aerobic rice under different treatments was worked out as:

Water productivity (kg ha-cm^{-1})=Grain yield (kg ha^{-1})/ Quantity of total water applied (cm)

Nutrient use efficiency (NUE) for nutrients like nitrogen, phosphorus and potassium was worked out by using following formula and expressed as kg kg^{-1}:

NUE= [Grain yield (kg ha^{-1})/ Nutrient applied (kg kg^{-1})] 100

The data obtainedwere subjected to statistical analysis given by Gomez and Gomez (1984). Least significant difference (LSD) values at p=0.05 were used to interpret the treatment differences.

3. Results and Discussion

3.1. Effect on water use and water productivity

The results from the study reveals that drip fertigation at 1.5 PE up to maturity with 100% RDF through WSF recorded higher water productivity of 78.1 kg ha-cm^{-1} besides saving 39% of water as compared to surface irrigation (Table 1). Total water use was registered with surface irrigation method (1288.0 mm) followed by treatments having irrigation levels at 1.5 PE up to maturity (844.4 mm) and least total water used was with 1.0 PE up to tillering and 1.5 PE up to maturity (766.4 mm). The increase in water productivity in all drip

Sl. no.	Treatments	Irrigation water used (mm)	Total water use I_R+E_R (mm)	Water productivity (kg ha-cm^{-1})	% water saved
1.	Surface irrigation with soil application of RDF	1150	1288.0	26.9	-
2.	Drip irrigation (1.5 PE) with soil application of RDF	706	844.4	54.1	38.6
3.	Drip irrigation (1.0+1.5PE) with soil application of RDF	628	766.4	56.4	45.4
4.	Drip fertigation (1.5 PE) with 100% RDF through NF	706	844.4	64.6	38.6
5	Drip fertigation (1.5 PE) with 75% RDF through NF	706	844.4	60.9	38.6
6.	Drip fertigation (1.5 PE) with 50% RDF through NF	706	844.4	56.9	38.6
7.	Drip fertigation (1.0+1.5 PE) with 100% RDF through NF	628	766.4	63.0	45.4
8.	Drip fertigation (1.0+1.5 PE) with 75% RDF through NF	628	766.4	61.7	45.4
9.	Drip fertigation (1.0+1.5 PE) with 50% RDF through NF	628	766.4	60.1	45.4
10.	Drip fertigation (1.5 PE) with 100% RDF through WSF	706	844.4	78.1	38.6
11.	Drip fertigation (1.5 PE) with 75% RDF through WSF	706	844.4	64.7	38.6
12.	Drip fertigation (1.5 PE) with 50% RDF through WSF	706	844.4	58.2	38.6
13.	Drip fertigation (1.0+1.5 PE) with 100% RDF through WSF	628	766.4	70.0	45.4
14.	Drip fertigation (1.0+1.5 PE) with 75% RDF through WSF	628	766.4	66.9	45.4
15.	Drip fertigation (1.0+1.5 PE) with 50% RDF through WSF	628	766.4	61.7	45.4
SEm±		NA	NA	4.6	NA
LSD (p=0.05)		NA	NA	13.6	NA

Table 1: Total water used and water productivityof aerobic rice under drip fertigation

RDF: Recommended dose of fertilizers; PE: Pan evaporation; NA: Not analysed; NF: Normal fertilizers; WSF: Water soluble fertilizer; IR: Irrigation requirement; ER: Effective rainfall; 1.5 PE: 1.5 PE up to maturity; 1.5 PE: 1.0 PE up to tillering and 1.5 PE tillering to maturity

irrigated treatments over surface irrigation was mainly due to considerable saving of irrigation water, greater increase in yield of crop and higher nutrient use efficiency. This was in accordance with Chawla and Narda, 2001. These studies reveal that supplying water to soil and nearer to the plant without much loss of water resulting in higher water productivity.

3.2. Effect on growth attributes

Growth attributes like total number of tillers and total dry matter production were significantly affected by drip fertigation (Table 2). Drip fertigation at 1.5 PE up to maturity with 100% RDF through WSF recorded significantly higher number of total tillers (48.13 hill^{-1}) and produced higher dry matter hill^{-1} (118.40 g) than other treatments. This is mainly because of WSF through fertigation resulted in continuous supply of nutrients besides maintaining optimum water availability which lead to higher uptake of nutrients which in turn recorded higher growth attributes. Similar results have been obtained by Veeraputhiran et al. (2002); Vijay kumar (2009). Effect on yield attributes and yield

Drip fertigation significantly influenced the yield attributes of *aerobic* rice. Drip fertigation at 1.5 PE up to maturity with 100% RDF through WSF recorded higher productive tillers (27.77 hill^{-1}) panicle length (26.17 cm) , panicle weight (3.21 g), grains panicle^{-1} (170.80) and test weight of grains (25.33 g). Significantly higher grain and straw yield (Table 2) was recorded in drip fertigation at 1.5 PE up to maturity with 100% RDF through WSF (6598 and 11084 kg ha^{-1}, respectively) which was 90.3% higher than surface irrigation with soil application of 100% RDF (3467 and 5995 kg ha^{-1}, respectively) which was significantly lower and recorded 45.83 and 41.85% lower grain yield as compared to drip fertigation at 1.5 PE up to maturity with 50% RDF through WSF (4917 kg ha^{-1}) or NF (4800 kg ha^{-1}). The increase in the yield is related to higher leaf area index and crop growth rate which are contributed for assimilation of more photosynthates and resulted in superior yield attributes and yield. Such findings are in consonance with the findings of Muralidhar (1998); Latif (2001); Ali et al. (2005).

Table 2: Growth and yield attributes of aerobic rice as affected by drip fertigation

Trts.	Total tillers hill^{-1}	TDMP (g hill^{-1})	Productive tillers hill^{-1}	Grains panicle^{-1}	Panicle length (cm)	Panicle weight (g)	Test weight (g)	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})
1.	33.07	81.30	17.63	135.23	18.70	3.00	19.73	3467	5995
2.	38.10	88.10	23.73	156.19	21.43	3.28	21.03	4567	7632
3.	35.33	84.54	17.87	144.10	19.70	3.20	20.00	4319	6640
4.	41.65	114.15	25.13	167.62	24.93	3.97	23.67	5451	8704
5.	38.27	108.45	22.07	167.40	22.67	3.50	22.67	5141	8549
6.	38.17	104.15	21.10	163.94	22.33	3.42	22.20	4800	7899
7.	39.30	106.45	21.07	164.92	23.50	3.58	22.30	4831	8166
8.	38.27	101.55	19.10	162.48	22.27	3.31	22.20	4731	7910
9.	38.07	95.80	18.63	161.12	21.50	3.21	21.20	4603	6789
10.	48.13	118.40	27.77	170.80	26.17	4.23	25.33	6598	11084
11.	45.80	114.90	26.97	165.09	25.33	4.04	24.50	5470	9680
12.	39.30	111.60	26.30	158.51	24.23	3.88	23.67	4917	8885
13.	44.23	113.48	23.97	163.37	26.07	4.00	24.43	5365	9168
14.	41.30	111.38	22.27	159.84	23.83	3.74	23.93	5131	8741
15.	38.83	109.80	21.87	156.16	23.47	3.42	23.00	4731	8235
SEm±	2.54	1.47	1.62	4.48	1.50	0.25	0.58	389	753
LSD (p=0.05)	7.36	4.25	4.70	12.97	4.37	0.75	1.68	1129	2182

TDMP : Total dry matter production

3.3. Effect on nutrient uptake and nutrient use efficiency

Depending upon the varied amount of nutrient supply through drip fertigation and corresponding grain and straw yield, nutrient uptake nutrient use efficiency for elements like nitrogen, phosphorus and potassium showed significant difference, which is presented in Table 3. Drip fertigation at 1.5 PE up to maturity with 100% RDF through WSF shown higher nutrient uptake (142.58, 36.05 and 92.59 kg ha^{-1}, respectively) wherein drip fertigation at 1.5 PE up to maturity with 50% RDF through WSF registered higher NUE for N, P and K (98.3, 196.7 and 196.7 kg kg^{-1}, respectively) as compared to other treatments and also there was increased nutrient use efficiency with decrease in the nutrient levels. Also, water soluble fertilizers have given higher use efficiency of nutrients as compared to normal fertilizers with drip fertigation at 1.5 PE up to maturity. This was attributed to better availability of moisture and nutrients throughout crop growth stages in drip fertigation system leading to better uptake of nutrients, production of higher dry matter and in turn economic yield. This indicated that increased solubility resulted in improved uptake with lesser losses, even when lower doses of nutrients are applied as compared to higher

Table 3: Influence of drip fertigation on nutrient uptake and nutrient use efficiency of aerobic rice

Trts.	Nutrient uptake ($kg\ ha^{-1}$)			Nutrient use efficiency ($kg\ kg^{-1}$)		
	Nitrogen	Phosphorus	Potassium	Nitrogen	Phosphorus	Potassium
1.	104.17	25.08	64.40	34.7	69.3	69.3
2.	116.17	29.29	71.34	45.7	91.3	91.3
3.	112.17	27.91	67.96	43.2	86.4	86.4
4.	126.97	34.84	80.87	54.5	109.0	109.0
5.	123.77	33.97	78.20	68.6	137.1	137.1
6.	118.17	32.76	74.35	96.0	192.0	192.0
7.	122.83	33.11	78.12	48.3	96.6	96.6
8.	120.70	31.55	75.15	63.1	126.2	126.2
9.	118.17	30.33	72.27	92.1	184.1	184.1
10.	142.58	36.05	92.59	65.9	131.9	131.9
11.	137.17	34.93	89.17	72.9	145.8	145.8
12.	130.97	33.80	82.52	98.3	196.7	196.7
13.	136.57	34.84	84.89	53.7	107.3	107.3
14.	128.77	33.80	81.97	68.4	136.8	136.8
15.	124.37	33.11	80.26	94.6	189.2	189.2
SEm±	1.71	0.82	0.29	5.9	11.9	11.9
LSD (p=0.05)	4.96	2.40	0.84	17.3	34.7	34.7

levels. Such findings are in consonance with the findings of Muralidhar (1998); Latif (2001); Ali et al. (2005); Raina et al. (2011).

4. Conclusion

This indicated that drip fertigation at 1.5 PE up to maturity with 100% RDF through WSF will be the best treatment in getting higher growth and yield apart from higher water productivity. There could be a possibility of saving 50% fertilizer through drip fertigation by achieving comparable yield as that of 100% RDF. Further which is significantly higher as compared to surface irrigation with 100% RDF through soil application.

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