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RESEARCH ARTICLE

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Influence of Irrigation Methods and Nano-fertilizers Application on the Yield of Transplanted Lowland Rice (*Oryza sativa* L.) in Periyar Vaigai Command Area of Madurai

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ABSTRACT

Background: Rice production and productivity must be increased despite water scarcity and deterioration of soil fertility by imbalanced fertilizer application. To meet the demand of the ever growing population, the production level must be increased to cope with minimum inputs and enhanced input-use efficiency. Efficient and effective method of irrigation and fertilizer application could address the emerging issue.

Methods: The field study was conducted at the Agricultural College and Research Institute in Madurai to identify suitable irrigation methods and nutrient management practices with the aim of increasing the yield of rice under transplanted condition during *Kharif* 2022. The experiment was carried out in a split plot design with irrigation methods in the main plot and foliar spray of nano-fertilizers in combination with conventional fertilizers in the sub-plot.

Result: Yield characters such as number of productive tillers m^{-2}, panicle length (cm), panicle weight (g), number of grains and filled grains $panicle^{-1}$ were recorded in addition to grain and straw yield (kg/ha). From this study it could be concluded that, irrigation through alternate wetting and drying along with combined application of 50% N and K through straight fertilizers + Nano N and K applied as foliar spray recorded higher yield attributes and yield of rice.

Key words: Alternate wetting and drying, Field water tube, Nano fertilizers, Rice, Yield.

INTRODUCTION

Rice (*Oryza sativa* L.) is the most staple food crop grown extensively in world which feeds more than 60 per cent of the world's population residing in Asia and supplementing 35 to 60 per cent of their total calorie uptake (Pathak *et al*., 2018). Approximately 60-70 per cent of the energy requirement for humans is fulfilled by rice and its derived products for over two billion people worldwide (Anju, 2020). The catchphrase 'Rice is life' is true in the case of countries like India, where it holds a vital place in the nation's food security and livelihood for many rural households.

In terms of area under rice cultivation, India ranks first while in production it's next to China yet it shares 45.7 m ha of area with 124.3 m t production and 2.7 t ha^{-1} of productivity. In Tamil Nadu 2.03 m ha of area is under rice cultivation with production and productivity range of 6.8 m t and 3.3 t ha^{-1} (India stat, 2021).

In the agricultural sector, irrigated lowland rice is the largest consumer of freshwater resources and about 75 per cent of the worlds and 80 per cent of Asian water resources are devoted to its production (Bouman *et al*., 2007). Area under rice cultivation is about 167 million hectares globally in which 75 per cent of the area is under conventional irrigation method (FAO, 2018). Climate change and groundwater mining pose a serious threat to the availability of fresh water to the agricultural sector, with special attention paid to irrigated rice (Farooq *et al*., 2009). Nearly 2 m ha of Asia's irrigated dry season rice and 13 mha of irrigated wet season rice could face "physical water scarcity" and about 22 mha of irrigated dry season rice in South and South East Asia could undergo "economic water scarcity" (Ullah *et al*., 2018). Farmers usually prefer rice cultivation under flooded conditions, assuming that higher yields can be achieved by this irrigation method. Improving irrigation efficiency is a practical way to increase

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the water-saving percentage with appropriate method, time and amount of irrigation water applied. Thus far encouraging the above fact, an alternate water-saving irrigation method must be adopted. One such technique is IRRI's alternate wetting and drying method a vision to increase water use efficiency in rice crop with reduced water input, in which the field is allowed to dry for 2 to 4 days and then re-flooded (Kannan *et al*., 2017). Scheduling of irrigation is necessary and the soil properties make it difficult to evaluate the right time to irrigate. Field water tube (FWT) is a simple and convenient tool for measuring the water level in rice fields ensuring the application of right amount of water at the right time, thus in assuring safe alternate wetting and drying (AWD) saves 15 to 30 per cent of water (Anju, 2020).

Fertilizers are inevitable since from the introduction of fertilizer responsive crops through green revolution. Imbalanced and overuse of fertilizers have deteriorated the soil fertility status. In such cases, alternative cum innovative approaches are needed to keep up the production level, meeting the crop's nutrient demand *etc*. Nano technology could add solutions to the above issues. Nano fertilizers are made by encapsulating plant nutrients into nano materials, which are provided in the form of nano sized emulsions, ensuring quality food production with reduced impact on human health and the environment through which it creates vision for stable and sustainable agricultural crop production (Meena *et al*., 2021). Supplying nutrients through nano fertilizers ensures timely availability of nutrients, enhances the uptake by crops (Babubhai *et al*., 2019) and increases crop yield by 17-54 per cent (Rameshaiah *et al*., 2015). Nitrogen is the primary nutrient for plants and is a key factor in crop growth and development (Lahari *et al*., 2021). Potassium is a major contributor in determining the yield and quality of crops (Sharma *et al*., 2005). Application of N and K in the form of foliar spray directly on leaves is more efficient and effective than the soil application method (Al Juthery *et al*., 2018).

Thus, the use of nano fertilizers with reduced irrigation regimes ensures savings in fertilizer and water input levels without much reduction in yield. The present experiment was carried out to evaluate the suitable irrigation method and ideal nutrient management practices in transplanted rice.

MATERIALS AND METHODS

Study area

The field experiment was conducted on sandy clay loam soil at Agricultural College and Research Institute, Madurai during *Kharif* 2022 which is situated in the southern zone of TamilNadu at 9°54′N latitude and 78°54′E longitude with an altitude of 147 m above MSL. It was medium in nitrogen (241.2 kg ha^{-1}) and in phosphorus (16.2 kg ha^{-1}), high in potassium (332.5 kg ha^{-1}) with alkaline pH of 8.1 and EC of 0.47 dsm^{-1}. During the cropping period, total rainfall of 413.9 mm was received in 21 rainy days. The average maximum and minimum temperature recorded were 34.7°C and 24.1°C. With regard to relative humidity, the mean RH of 81.1 per cent was recorded at 07:14 hours and 60.9 per cent was recorded at 14:14 hours with mean sunshine hours of 5.5 hours day^{-1}.

Treatments and design

Experiment was laid out in split plot design replicated thrice. Main plot consists of irrigation regimes *viz*., irrigation at 15 cm depletion of water level with field water tube (M_1), alternate wetting and drying (M_2) and conventional flooding (M_3). Nutrient management practices were adopted in the sub-plots, such as 50 percent N through straight fertilizer + Nano N as foliar spray (S_1), 75 per cent N through straight fertilizer + Nano N as foliar spray (S_2), 50 per cent K through straight fertilizer + Nano K as foliar spray (S_3), 75 per cent K through straight fertilizer + Nano K as foliar spray (S_4), 50 per cent N and K through straight fertilizers + Nano N and K as foliar spray (S_5), 100 per cent recommended dose of fertilizer (120:40:40 kg NPK ha^{-1}) (S_6) and absolute control (S_7). Short duration rice variety Co 54 was used in this study.

Imposition of alternate wetting and drying and field water tube irrigation

In alternate wetting and drying method, irrigation was given after the formation of hairline cracks in the field. Under irrigation given field water tube treatments, PVC pipe having 30 cm length and 15 cm diameter was taken in which 15 cm length of the pipe was perforated with holes of 0.5 cm diameter. The tube was kept open at both end and 15 cm of the perforated side is inserted into puddled soil. Soil accumulated inside the tube was removed periodically once in two weeks.

Crop management

Transplanting was done with 21 days old seedlings. The recommended dose of fertilizer 120:40:40 kg NPK/ha was supplied in the form of Urea, DAP and MOP (CPG 2021). Entire P was applied as basal whereas N and K were applied in three splits *viz*., basal, at active tillering and at panicle initiation stages. Nano urea and nano potash were applied as foliar spray at active tillering and at panicle initiation stages.

Observation on yield attributes and yield

Five plants were randomly selected from each treatment to observe yield attributes, such as number of productive tillers m^{-2}, panicle length (cm) and no. of grains $panicle^{-1}$ and no. of filled grains $panicle^{-1}$. Grain and straw yield (kg ha^{-1}) were computed for each treatment after harvest.

Statistical analysis

Data was analysed by using R software packages (R v.4.2.1) and means of treatments were compared based on the critical difference (C.D) test at five percent probability level.

RESULTS AND DISCUSSION

Number of productive tillers m^{-2}

Irrigation methods had significant impact on number of productive tillers m^{-2} (Table 1). Among the irrigation methods, alternate wetting and drying (M_2) recorded the maximum number of productive tillers m^{-2} (323). It was followed by conventional flooding (M_3) which recorded 302 number of productive tillers m^{-2}. Practicing the alternate wetting and drying irrigation method creates better aeration and root proliferation with optimum mobility of nutrients. It could enhance the absorption of nutrients from the soil resulted in higher productive tillers m^{-2}. Santheepan and Ramanathan (2016) observed similar result with their findings. Productive tillers m^{-2} was recorded least with (229) was observed in irrigation at 15 cm depletion level of field water tube (M_1). Since the crop was subjected to water stress it resulted in inability of the roots to uptake sufficient amount of nutrients resulted in lower number of productive tillers. Similar results were reported by Kannan *et al*. (2017), Anju (2020) and Arivukkumar *et al*. (2021).

Application of 50 per cent N and K through straight fertilizers + Nano N and K as foliar spray (S_5) recorded maximum number of productive tillers m^{-2} (354). Nutrient requirement of rice was met by inorganic sources at initial stages and by foliar application of nano fertilizers at subsequent stages, enhanced the nutrient uptake which contributed for higher number of productive tillers. This was followed by application of 75 per cent N through straight fertilizer + Nano N as foliar spray (S_2) recorded 337 productive tillers m^{-2}. The minimum number of productive tillers m^{-2} (156) were obtained with absolute control (S_7).

On interaction, alternate wetting and drying method of irrigation with 50 percent N and K through fertilizer + Nano N and K as foliar spray (M_2S_5) recorded the maximum no. of productive tillers m^{-2} (408). It was statistically on par with alternate wetting and drying method of irrigation coupled with application of 75 per cent N through straight fertilizer + Nano N as foliar spray (M_2S_2) (401) and conventional flooding method with 50 per cent N and K through straight fertilizers + Nano N and K as foliar spray (M_3S_5) (382). Adequate availability of moisture and nutrients might have increased translocation and photosynthetic efficiency, which resulted in enhanced the productive tillers m^{-2}. Minimum number of productive tillers m^{-2} were obtained in irrigation with 15 cm depletion of field water tube with absolute control (M_1S_7) (238). Deficient moisture and nutrient supply would have resulted in reduced number of productive tillers m^{-2}. This is in accordance with findings of Kumar *et al*., (2014) and Kannan *et al*. (2017).

Panicle length and weight

Panicle length (cm) and panicle weight (g) were significantly influenced by different irrigation methods and nutrient management strategies (Table 1). They were found to be maximum (21.9 cm and 3.99 g) under alternate wetting and drying (M_2) and followed by conventional flooding (M_3) which recorded 20.7 cm and 3.75 g of panicle length and weight. Adequate moisture supply had a positive impact on panicle length and weight. Similar finding was reported by Santheepan and Ramanathan (2016) and Arivukumar *et al*. (2021). Irrigation with field water tube at 15 cm depletion level from the surface of the soil (M_1) resulted on the minimum panicle length (15.8 cm) and weight of the panicle (2.73 g). This could be due to increased water scarcity during the entire growth stage of the crop. Similar result was noticed by Kannan (2012).

With respect to nutrient management strategies, application of 50 per cent N and K through straight fertilizer + Nano N and K as foliar spray (S_5) produced the panicle with higher length (24.2 cm) and weight (4.46 g). Combined application of nano N and K would have favoured adequate supply of nutrients. It was statistically followed by 75 per cent N through straight fertilizer + Nano N as foliar spray (S_2) (22.4 cm and 4.10 g). Both panicle length (11.2 cm) and weight (1.79 g) were found to be minimum with absolute control (S_7).

On combination, alternate wetting and drying method of irrigation combined with 50 per cent N and K application through straight fertilizer + Nano N and K as foliar spray

Table 1: Effect of irrigation and nutrient management strategies on productive tillers (m^{-2}), panicle length (cm) and panicle weight (g) of rice during *Kharif* 2022.

Treatments	Productive tillers m^{-2}				Panicle length (cm)				Panicle weight (g)			
	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean
S_1	236	314	296	282	16.2	21.5	20.3	19.3	2.81	3.91	3.66	3.46
S_2	262	401	347	337	18.0	25.6	23.7	22.4	3.19	4.76	4.36	4.10
S_3	221	295	281	266	15.1	20.0	19.2	18.1	2.61	3.61	3.44	3.22
S_4	238	338	327	301	16.3	23.2	22.5	20.7	2.84	4.25	4.12	3.74
S_5	272	408	382	354	18.6	27.9	26.0	24.2	3.32	5.20	4.87	4.46
S_6	238	337	322	299	16.3	23.0	22.0	20.4	2.84	4.21	4.02	3.68
S_7	138	169	161	156	10.0	12.3	11.3	11.2	1.54	2.02	1.81	1.79
Mean	229	323	302		15.8	21.9	20.7		2.73	3.99	3.75	
	M	**S**	**M at S**	**S at M**	**M**	**S**	**M at S**	**S at M**	**M**	**S**	**M at S**	**S at M**
S.Ed	6.21	9.13	15.91	15.81	0.38	0.55	0.96	0.96	0.08	0.13	0.22	0.22
CD (P=0.05)	17.2	18.5	34.1	32.1	1.05	1.12	2.06	1.94	0.22	0.26	0.48	0.46

(M_2S_5) recorded maximum panicle length (23.0 cm) and weight (4.21 g). Adequate moisture and nutrient supply at the needed time might have enhanced the panicle length and weight. Similar result was obtained by Kumar *et al*. (2013). The minimum length (10.0 cm) and weight (1.54 g) were obtained under irrigation with 15 cm depletion level of field water tube with absolute control (M_1S_7).

Number of grains panicle^{-1}

Number of grains panicle^{-1} is the outcome of higher leaf area index and dry matter production. It was significantly influenced by irrigation and nutrient management practices (Table 2). Number of grains panicle^{-1} was observed maximum (238) with alternate wetting and drying irrigation (M_2). The increased translocation of assimilates from the source to the sink enhanced the number of grains panicle^{-1}. This was followed by conventional flooding (M_3) (226). Number of grains panicle^{-1} was found to be minimum in irrigation with field water tube at 15 cm depletion level from the surface of the soil (M_1). Minimum number of irrigations associated with insufficient availability of water reduced the nutrient uptake which might be the reason for least number of grains panicle^{-1} (173) recorded under this irrigation regime.

Application of 50 per cent N and K through straight fertilizers + Nano N and K as foliar spray (S_5) resulted in maximum no. of grains panicle^{-1} (267). Timely supply of nutrients through nano fertilizers by foliar spray stimulated the grain formation which resulted in higher quantity of grains/panicle. Similar result was obtained by Sahu *et al*. (2022). Further it was statistically followed by 75 per cent N through fertilizer + Nano N as foliar spray (S_2) which recorded 245 grains panicle^{-1} and minimum (107) was recorded under absolute control (S_7).

On combination impact, alternate wetting and drying method of irrigation with 50 per cent N and K through straight fertilizers + Nano N and K as foliar spray recorded the maximum (244) no. of grains panicle^{-1} (M_2S_5). Combination of conventional irrigation and nano fertilizers application as foliar spray increased the assimilation and translocation of photosynthates to economic part of plants which resulted in higher number of grains panicle^{-1}. This is similar with finding as reported by Ahmadian *et al*. (2021). Minimum number of grains panicle^{-1} (106) was obtained by irrigation with a 15 cm depletion level of field water tube with absolute control (M_1S_7). Deficient moisture and nutrient supply resulted in reduced no. of grains/panicle.

Number of filled grains panicle^{-1}

Irrigation regimes and nutrient levels had a considerable impact over no. of filled grains panicle^{-1} (Table 2). It was maximum (185.7) with alternate wetting and drying regime (M_2), which eased the mobilization of photosynthetic assimilates from the source (green parts of the crop) to the sink (economic part), resulting in enhanced grain filling. This finding is consistent with that of Anju (2020). However, this was followed by conventional flooding regime (M_3) (176) and the minimum (133.6) was attributed by irrigation with field water tube when the water level was depleted to 15 cm below the soil surface (M_1). Moisture stress during the reproductive phase affected biomass production and assimilated translocation, which was attributed to lower grain filling (Arivukumar *et al*., 2021).

Application of 50 per cent N and K through straight fertilizers + Nano N and K as foliar spray (S_5) resulted in maximum no. of filled grains panicle^{-1} (205). Foliar application of nano fertilizers enhances nutrient uptake through the controlled release of applied nutrients. This provided a sufficient quantity of nutrients for a prolonged period, which was attributed to the higher grains/panicle. Similar results were reported earlier by Saitheja *et al*. (2022) for black gram. This was followed by 75 per cent N through fertilizer + Nano N as foliar spray (S_2) (190). The minimum filled grains panicle^{-1} (94) was accounted in absolute control (S_7) treatment. The unavailability of nutrients at critical stages resulted in lower dry matter accumulation at the grain-filling stage, which ultimately reduced filled grains panicle^{-1}.

Table 2: Effect of irrigation and nutrient management strategies on no. of grains panicle^{-1}, no. of filled grains panicle^{-1} and Sterility percentage of rice during *Kharif* 2022.

Treatments	No. of grains panicle^{-1}				No. of filled grains panicle^{-1}				Sterility percentage*			
	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean
S_1	176	231	221	210	137	182	172	164	22.3	21.0	22.5	21.9
S_2	195	283	256	245	152	216	201	190	22.0	23.5	21.3	22.3
S_3	164	215	207	195	128	171	164	154	21.8	20.6	20.9	21.1
S_4	179	248	243	224	138	197	191	175	23.2	20.6	21.3	21.7
S_5	205	308	287	267	158	236	221	205	23.2	23.4	21.3	22.7
S_6	182	244	242	222	137	196	186	173	24.5	19.9	23.3	22.6
S_7	106	134	125	122	85	102	95	94	20.2	23.7	24.0	22.6
Mean	173	238	226		134	186	176		22.4	21.8	22.1	
	M	**S**	**M at S**	**S at M**	**M**	**S**	**M at S**	**S at M**				
S.Ed	4.32	5.99	10.54	10.38	3.59	5.45	9.45	9.44				
CD (P=0.05)	12.1	12.2	22.7	21.1	9.9	11.1	20.2	19.2				

*Data not statistically analysed.

Table 3: Effect of irrigation and nutrient management strategies on grain yield (kg ha^{-1}), straw yield (kg ha^{-1}) and harvest index of rice during *Kharif* 2022.

Treatments	Grain yield (kg ha^{-1})				Straw yield (kg ha^{-1})				Harvest index*			
	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean
S_1	3370	4478	4226	4025	4482	6045	5667	5398	0.429	0.426	0.427	0.427
S_2	3745	5344	4945	4678	4985	7198	6636	6273	0.429	0.426	0.427	0.427
S_3	3159	4180	4011	3783	4198	5643	5379	5074	0.429	0.426	0.427	0.427
S_4	3400	4830	4695	4308	4529	6521	6305	5785	0.429	0.426	0.427	0.427
S_5	3887	5797	5461	5048	5209	7826	7355	6797	0.427	0.426	0.426	0.426
S_6	3394	4791	4593	4259	4528	6458	6200	5729	0.428	0.426	0.426	0.427
S_7	2074	2568	2346	2329	2763	3467	3146	3125	0.429	0.426	0.427	0.427
Mean	3290	4570	4325		4385	6166	5813		0.429	0.426	0.427	
	M	**S**	**M at S**	**S at M**	**M**	**S**	**M at S**	**S at M**				
S.Ed	81.94	117.36	205.27	203.28	110.50	161.01	280.85	278.89				
CD (P=0.05)	227.5	238.1	440.8	412.3	306.8	326.6	602.2	565.6				

*Data not statistically analysed.

Among the interaction, alternate wetting and drying irrigation combined with 50 per cent N and K through fertilizer + Nano N and K as foliar spray (M_2S_5) recorded higher (236) filled grains panicle^{-1}. Optimum moisture and nutrient supply increased the uptake of nutrients and translocation of assimilates resulted in higher filled grains panicle^{-1}. It was confirmed by Kannan *et al*. (2017). It was found lower (85) in irrigation with 15 cm depletion of field water tube from the soil surface with absolute control (M_1S_7). These results are in agreement with those reported by Kumar and Shivay (2004).

Irrigation methods and nutrient management practices on yield

Irrigation and nutrient management strategies had significant impact on rice grain and straw yield of rice (Table 3). Alternate wetting and drying method (M_2) recorded the maximum grain (4570 kg ha^{-1}) and straw yield (6166 kg ha^{-1}) which was followed by conventional flooding (M_3). Repeated cycles of wetting and drying would allow better aeration of roots and enhanced nutrient uptake, ultimately led to higher grain and straw yield. The yield was minimum when irrigation with 15 cm depletion level of field water tube (M_1) from the surface level which recorded 2329 kg ha^{-1} of grain and 4385 kg ha^{-1} of straw yield. This could be because of reduced soil moisture and water stress might have affected the translocation of photosynthates from source to sink, resulting in reduced yield compared to other treatments. These findings are consistent with those of Santheepan and Ramanathan (2016).

Among the nutrient management practices, both grain and straw yield was found to be maximum (5048 and 6797 kg ha^{-1}) with the application of 50 per cent N and K through straight fertilizers + Nano N and K as foliar spray (S_5) and it was followed by the application of 75 per cent N through straight fertilizer + Nano N as foliar spray (S_2) (4678 and 6273 kg ha^{-1}). Foliar application of nano fertilizers might have enhanced the uptake of nutrients, thereby increased the biomass and yield attributes and ultimately increased the yield (Al Juthrey *et al*., 2018). This might be due to the synergistic effect of nanofertilizers on the efficacy of conventional fertilizers, which resulted in increased nutrient absorption by plant cells. This, in turn, improved the photosynthate accumulation and translocation to the economic parts of the plant, which led to a higher yield. The minimum grain (2329 kg ha^{-1}) and straw yield (3125 kg ha^{-1}) were obtained in the absolute control (S_7).

Grain and straw yield were significantly influenced by a combination of various irrigation methods and nutrient management practices. Sufficient water and nutrient supply throughout the crop growth period enhanced the assimilate translocation from source to sink, thus increased the yield attributes, which ultimately contributed to higher yield with alternate wetting and drying irrigation methods along with the application of 50 per cent N and K through fertilizer + Nano N and K as foliar spray (M_2S_5) (5797 and 7826 kg ha^{-1}). Both grain and straw yield were found to be minimum (2074 and 2763 kg ha^{-1}) in irrigation at 15 cm depletion level from the soil surface with absolute control (M_1S_7). The scarcity of water and nutrients at critical stages of rice growth might have reduced the source and sink ratio, which hampered the yield attributes that were reflected in grain and straw yield. This was in accordance with the results reported by Kumar *et al*. (2014).

CONCLUSION

Based on the above results, it is concluded that alternate wetting and drying irrigation combined with the application of 50 per cent N and K through straight fertilizers + Nano N and K as foliar spray resulted in higher yield attributes and yield of rice. Practicing alternate wetting and drying regime and nano fertilizer application would also reduce the amount of water and fertilizers in transplanted rice.

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Conflict of Interest

The authors declare that there is no conflict of interests regarding the publication of this article.

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