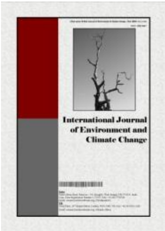

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Effect of Precision Water and Nitrogen Management on Yield Attributes and Yield of Aerobic Rice under Drip System

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

A Field experiment was conducted at Indian Institute of Rice Research (IIRR) during *Rabi* season of 2020 and 2021, with an objective to study the effect of precision water and nitrogen management on yield attributes and yield of aerobic rice under drip system. Treatments included three precision irrigation management methods- {I_1 (DRIP irrigation 1.5 Epan in Flat bed system); I_2 (DRIP irrigation 1.5 Epan in Raised bed system) and I_3 {Surface irrigation (up to saturation)}} and four precision nitrogen management practices- N_1 {Recommended practice (RDF)-(120:60:40 N P K kg ha^{-1})}; N_2 {Green seeker (Optical sensor) based N application}; {N_3 (LCC based N application) and N_4 (No Nitrogen)} replicated thrice. Results of experiment shows that, the performance of aerobic rice was

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better when it was managed with precision 'N' management tools like LCC based 'N' application with surface method of irrigation in terms of recording higher yield attributes and yield. Among irrigation methods, higher values of yield attributes such as no of panicles m^{-2} (144), length of panicle (21.7 cm), panicle weight (3.4 g), filled grains $panicle^{-1}$ (109.3), total grains $panicle^{-1}$ (128.7), test weight (21.6 g), grain yield (4171 kg ha^{-1}) and lowest sterility percentage (15.6%) were observed under surface irrigation followed by drip irrigation with raised beds during both years (mean). Significantly higher values for above parameters were recorded under LCC based N application (148, 21.7 cm, 3.5 g, 114.5, 132.4, 21.5 g, 4230 kg ha^{-1} and 13.7%) followed by recommended practice among nitrogen management practices. The experimental data revealed that, cultivating rice under aerobic ecosystem with drip irrigation along with precision nitrogen management tools like LCC and greenseeker aids in recording high yield and yield attributes besides saving water and nutrients.

Keywords: Aerobic rice; drip irrigation; raised beds; precision tools; nitrogen; LCC greenseeker and yield.

1. INTRODUCTION

Rice (*Oryza sativa* L.) is the most important staple food crop that supplies major source of calories for about 45 per cent of world population, particularly to the people of Asian countries. Rice stands second in the world after wheat in area and production which occupies 43.5 M ha of area producing about 104.41 M t with productivity of 3.60 t ha^{-1} [1] in India. Telangana state contributes 2.09 M ha area with a production of 6.62 M t and an average productivity of 3295 kg ha^{-1} during 2016-17 [2] which is utilised by one third of world population.

Water and fertilizer are the two basic inputs in agriculture. The time is not too far off when water becomes scarce and costlier due to increased industrialisation and intensive agriculture. Efficient utilisation of available water resources is crucial for a country like India, which shares 17 per cent of the global population with only 2.4 per cent of land and 4 per cent of the water resources [3].

Rice crop requires very large amount of water for cultivation under the traditional flood irrigation method. There is an urgent need to develop water saving irrigation techniques that require less irrigation water than the traditional methods. Worldwide, new rice cultivation practices are being evaluated due to the need for saving water in the face of increasing shortage. In the words of Dr. Bouman, rice irrigation scientist at IRRI, Philippines. "We may have to change the way rice is produced in the future" and a new theme "Grow more rice with less water" is gaining attention in all the rice growing regions.

Aerobic rice is one such water saving technology, which concentrates in direct seeding and irrigation intermittently in contrast to the practice of raising nursery, puddling, transplantation, and submergence. Aerobic cultivation was designed to enhance water use efficiency, by growing in non-puddled, non-flooded fertile soils under irrigation and high external inputs [4].

Drip irrigation is another water saving system in which, precise amount of water is applied to the soil surface directly in the plant root zone to reduce evaporation loss. The slow rate of water flow allows more time for the water to soak into the soil resulting in less runoff thereby improving water use efficiency.

Land configuration plays a major role in minimizing soil erosion and improving water and nutrient use efficiency of field crops [5]. Conventional rice growing layouts and practices have several disadvantages like soil structural degradation during the rice phase and during harvest (especially in wet years), poor water management and waterlogging of drill sown rice and of crops grown in rotation with rice and restrictions of cropping sequence flexibility. Recently, rice growers have adopted bankless channel systems as an irrigation layout. This layout, when combined with permanent raised beds, offers opportunity to move from rice to other crops without altering irrigation layouts. Such raised bed systems can be an alternative solution to reduce waste of water use and adapt to climate conditions with low and erratic rainfall. It has been proven to be able to save water, as well as to improve the stability of soil aggregates [6].

Nitrogen fertilization is one of the major agronomic practice that affects yield and quality of rice crop, which is required at early and mid tillering stages to maximize the yield attributes. Since farmers generally prefer to keep leaves of the crop dark green presuming to get high yields of rice, and have a tendency of applying fertilizer N in excess of crop requirements. A large portion of applied N can escape the soil-plant system through leaching, ammonia volatilization and runoff loss to reach water bodies and atmosphere, creating pollution problems also [7]. The emphasis is now shifted from reducing N losses to matching crop N demand with fertilizer N supply for achieving high N use efficiency and the research has been oriented more towards finding ways and means to apply fertilizer N in real-time using crop demand-driven and field-specific needs.

Spectral properties of rice leaves measured through visual comparison, such as reading the intensity of green colour of leaves using a leaf colour chart can be used for managing crop demand-driven need-based fertilizer N application in rice. Leaf colour chart (LCC) is a simple, quick, low-cost tool and non destructive method for estimating the plant nitrogen status. LCC provides an indirect assessment of leaf nitrogen status, which is closely related to photosynthetic rate [8]. By comparing the reflection of the light from the leaf surface and different panels on the LCC, the relative leaf N status is estimated in terms of leaf greenness.

Leaf colour chart though it provides instantaneous results in scheduling nitrogen application, but they do not take into account the biomass of crop. Spectral vegetation indices such as normalized difference vegetation index (NDVI) are useful for indirectly obtaining information such as photosynthetic efficiency, productivity potential and potential yield [9] which can be measured by optical sensors. Greenseeker optical sensors use visible and NIR spectral response from plant canopies to detect N stress. Chlorophyll contained in the palisade layer of the leaf absorbs 70 to 90 per cent of all incident light in the red wavelength band. The reflectance of the NIR electromagnetic spectrum (720-1300 nm) depends upon mesophyll cells which scatter and reflect as much as about 60 per cent of all incident NIR radiation [10].

Not much research was conducted on raised bed and use of precision 'N' management tools in aerobic rice under drip irrigation system. In view of the above facts, the present experiment entitled "Precision water and nitrogen management in aerobic rice under drip system" has been proposed.

2. MATERIALS AND METHODS

The field experiment was conducted during *Rabi* 2020-2022 at Indian Institute of Rice Research (IIRR), Rajendranagar, Hyderabad, Telangana. The geographical location of the experimental site was 17^0 19" N and 78° 23" E Longitude with an altitude of 542 m above mean sea level. Agro-climatologically the area is classified as Southern Telangana Agro Climatic Zone of Telangana State. Experimental soil was clay loam in texture, moderately alkaline in pH (8.22), non-saline in reaction (0.23 dS m^{-1}), low in organic carbon content (0.46%). The chemical properties of soil revealed that the soil was low in nitrogen (184.2 kg ha^{-1}), medium in phosphorus (33.4 kg ha^{-1}) and high in potassium (482.7 kg ha^{-1}). Rice variety selected for the study was DRR Dhan-42. All agronomic practices were carried out as per the recommendations. The treatments were divided into horizontal and vertical strips with Strip plot design. The horizontal strip was further divided into three irrigation management methods and vertical strips were divided into four nutrient management methods. Details of the treatments with their corresponding symbols used in the experiment are presented below:

Horizontal Strips: (PRECISE WATER MANAGEMENT)

I_1: DRIP irrigation 1.5 Epan in Flat bed system
I_2: DRIP irrigation 1.5 Epan in Raised bed system
I_3: Surface irrigation **(**up to saturation)

Vertical Strips: (PRECISE NITROGEN MANAGEMENT)

N_1: Recommended practice (RDF)- (120:60:40 N P K kg ha^{-1})
N_2: Green seeker (Optical sensor) based N application
N_3: LCC based N application
N_4: No Nitrogen

The raised beds were freshly prepared (during both years) mechanically by a bed planter and were 80 cm wide, separated by furrows that were designed to be 20 cm wide and 20 cm deep. Direct seeding of dry seeds was done manually during both the years at 20 cm x 10 cm spacing wherein 4 rows are accommodated in each bed.

To separate the effect of water management from that of the raised beds themselves, the same row spacing was used in the flat-bed and surface irrigation treatments.

2.1 Irrigation Management

The irrigation water was applied through drip system in raised and flatbed treatments on the basis of pan evaporation (PE) data obtained from (USWB open pan evaporation) installed at the Agroclimatic Research Centre, ARI, Rajendranagar, Hyderabad. Irrigation was given from sowing to 8 days before harvest through drip irrigation. First irrigation was given immediately after sowing and subsequent irrigations were scheduled once in 2 days based on daily pan evaporation through drip system. The quantity of applied water to each treatment was measured with the help of water meter. During rainy days, the volume of water applied to each treatment was adjusted for the effective rainfall received. Separate valves were provided in drip system for regulating water supply in each plot. In surface irrigation treatment flooding upto field capacity was done daily. To prevent seepage flows between aerobic and surface irrigated plots, the flooded plots were separated by a strip of bare soil of 2 m width from the aerobic plots.

The quantity of water was calculated as follows [11]:

$$\text{Application rate (mm per hr)} = \frac{\text{Q}}{\text{DL x DE}}$$

Whereas

Q = Dripper discharge (liters h^{-1})
D_L = Distance between lateral spacing (m)
D_E = Distance between dripper (emitters) spacing (m)

Irrigation time for each treatment was calculated using the following formula [11]:

$$\text{Irrigation (minutes)} = \frac{\text{Epan(mm)x 60}}{\text{Application rate (mm per hr)}}$$

2.2 Nutrient Management

Basal soil application of $ZnSO_4$ @ 25 kg ha^{-1}, $FeSO_4$ @ 50 kg ha^{-1} and $MgSO_4$ @ 2 kg ha^{-1} was done to prevent Fe and Zn deficiency. Also foliar sprays of 0.5% $ZnSO_4$ and 1 % $FeSO_4$ was taken up at tillering and panicle initiation stages. The recommended dose of fertilizer @ 120-60-40 kg NPK ha^{-1} was applied. NPK were applied through Urea, Single Super Phosphate and Muriate of Potash in aerobic rice. For N_1 treatment nitrogen was applied as 20 % at 15 DAS, 30% at (tillering and Panicle Initiation) and 20% at flowering stage. Recommended dose of nitrogen was applied along with irrigation water through fertigation to improve the fertilizer use efficiency in drip irrigated plots. Nitrogen @ 20 kg ha^{-1} was applied as basal and remaining dose (15 kg ha^{-1} each time) was applied based on the treatments (N_2 and N_3) that included precise nitrogen management tools like Green seeker and Leaf colour chart, as and when the threshold levels {(NDVI-0.40, 0.70, 0.65 and 0.35 for Initial, Crop development, Reproductive and Late season stages respectively) and (LCC threshold value-3)} have reached. Nitrogen was avoided for N_4 treatment (Zero Nitrogen).

2.3 LCC Observation

The topmost fully expanded leaf from each hill was selected and leaf colour was compared by placing the middle part of the leaf on LCC and the leaf colour was observed. Whenever the green colour of more than 5 out of 10 leaves were observed equal to or below a set critical limit of LCC score, nitrogen was applied as per the treatment. The leaf was not detached or destroyed. The average LCC reading were determined for each treatment. Readings were taken in the morning (8-10 AM) under the shade of body in order to avoid the influence of sun light as it may reflect the LCC colour.

2.4 Greenseeker Observation

Normalized Difference Vegetative Index (NDVI) is a measure of the total biomass and greenness of leaves was measured using greenseeker [12].

$$\text{NDVI} = (\text{NIR}_{\text{ref}} - \text{RED}_{\text{ref}}) / (\text{NIR}_{\text{ref}} + \text{RED}_{\text{ref}})$$

Where, NIR_{ref} or RED_{ref} represents reflectance in the near infrared and red wavebands.

NDVI values can range from 0.00 to 0.99. Higher the reading, healthier the plant. The value 0 represents absence of vegetation. The peak value within the N-rich strip (RDF) and value typical of N_2 treatment were used as two inputs and then referenced on the fertilizer estimation chart to determine the application rate of nitrogen. These spectral properties were measured at weekly interval starting from 21 days after sowing (DAS) to 50 % Flowering. Whenever the observed NDVI values fall below the threshold value, nitrogen was applied immediately to meet the N requirement irrespective of the stage of the crop.

Observations on yield attributes like no of panicles m^{-2}, length of panicle, panicle weight, filled grains panicle^{-1}, total grains panicle^{-1}, sterility percentage and test weight during maturity stage were done. Ten hills per plot were randomly marked with wooden sticks and tagged with luggage labels for recording various observations pertaining to the yield attributes.

3. RESULTS AND DISCUSSION

3.1 Effect of Precision Water and Nitrogen Management on Yield Attributes of Aerobic Rice

The data presented in the Tables 1 and 2 showed significant variation in yield attributes of rice v*iz*., no of panicles m^{-2}, length of panicle, panicle weight, filled grains panicle^{-1}, total grains panicle^{-1}, sterility percentage and test weight due to irrigation and N management treatments.

Data indicated that, no. of panicles m^{-2} was significantly influenced by irrigation and nitrogen management practices during both the years (Table 1). Highest number of panicles m^{-2} (136 and 151) under irrigation treatments was recorded with I_3 treatment {Surface irrigation (up to saturation)} which was on par with I_2 (DRIP irrigation 1.5 Epan in Raised bed system) (122 and 136) and differed significantly with I_1 treatment (DRIP irrigation 1.5 Epan in Flat bed system) (108 and 124) during 2020 and 2021 respectively. Higher number of panicles observed with surface irrigation might be due to favourable moisture conditions during panicle initiation stage which was beneficial in maintaining normal cell integrity, cell division and elongation apart from enhancing nutrient uptake (Singh, 2004) and finally led to increased sink size. Lowest panicles m^{-2} under flat bed with drip irrigation might be due to moisture stress conditions that resulted in reduction of productive tillers. Similar results were observed by Kalyan et al. [13].

In general, the Nitrogen management treatments did not differ significantly among themselves with respect to no. of panicles m^{-2}, but were significantly higher than the control (No Nitrogen). Highest number of panicles m^{-2} were recorded with N_3 (LCC based N application) treatment (140 and 157) which was at par with N_1 {Recommended practice (RDF)- (120:60:40 N P K kg ha^{-1})} (136 and 150) and N_2 {Green seeker (Optical sensor) based N application} (132 and 146) and significantly lowest no. of panicles m^{-2} (79 and 96) were registered by N_4 (No Nitrogen) during respective years.

Supply of nitrogen at sufficient levels matching with the crop need might have favoured structural and functional activities of the crop, resulting in production of more number of effective tillers. The lowest number of panicles m^{-2} with control (No nitrogen) might be due to insufficient supply of nitrogen for better growth and development of crop. Similar findings were reported by Avijith et al. [14] and Ramana et al. [15].

Panicle length and panicle weight as they are genetic characters, no significant differences were found due to irrigation and N management practices during both the years (Table 1). However, numerically highest values for above parameters (21.5 cm and 3.3 g during 2020) and (21.9 cm and 3.6 g during 2021) were recorded with I_3 treatment {Surface irrigation (up to saturation)}, while lowest values {(20.6 cm and 3.0 g) and (20.7 cm and 3.1 g)} was observed with I_1 treatment (DRIP irrigation 1.5 Epan in Flat bed system) under irrigation management during both years. Similarly, N_3 (LCC based N application) treatment {(21.6 cm and 3.4 g) and (21.9 cm and 3.5 g)} recorded higher values and N_4 (No Nitrogen) registered lowest values {(20.0 cm and 2.8 g) and (20.4 cm and 3.0 g)} under nitrogen management during respective years.

The data presented in the Table 2, showed that, filled grains panicle^{-1} and total grains panicle^{-1} were significantly influenced by irrigation and N management practices during both the years. Significantly highest values for above parameters {(104.3 and 125.5 during 2020) and (114.2 and 131.9 during 2021)} under irrigation management were recorded with I_3 treatment {Surface irrigation (up to saturation)}. While lowest values were recorded with I_1 treatment (DRIP irrigation 1.5 Epan in Flat bed system) {(84.5 and 108.8) and (91.2 and 115.5)} during respective years. Similar results were reported by Duary and pramanik [16] and Bhatta et al. [17].

The reduction in total spikelet production under reduced water supply in flat beds with drip irrigation might be due to the abortion of spikelets in the secondary rachis branch, as documented by Kato et al. [18] in aerobic rice. These results are in accordance with the findings of Anusha et al. [19].

In general, the Nitrogen management treatments did not differ significantly among themselves with respect to filled grains panicle^{-1} and total grains panicle^{-1} but were significantly higher than the control (No Nitrogen). Highest values {(108.6 and 126.2 during 2020) and (120.5 and 138.6 during 2021)} were recorded with N_3 (LCC based N application) treatment which was at par with N_1 {Recommended practice (RDF)-(120:60:40 N P K kg ha^{-1})} {(101.5 and 123.3) and (107.5 and 126.5)} and N_2 {Green seeker (Optical sensor) based N application} {(99.6 and 120.7) and (104.4 and 125.0). Significantly lowest values {(68.0 and 96.9) and (73.0 and 101.2)} were registered by N_4 (No Nitrogen) during both years under nitrogen management. These findings are consistent with those of Ramana et al. [15].

Increase in filled grain panicle^{-1} under precision nitrogen management using LCC might be due to synchronized nitrogen supply with the nutritional demand of rice at all the stages, which might have induced enhancement of photosynthetic activity resulting in the translocation of photosynthates and amino acids from the leaves and culms to the grain.

Sterility percentage was significantly influenced by irrigation and N management practices during both the years (Table 2). During 2020, lowest sterility percentage (17.4) was recorded with I_3 {Surface irrigation (up to saturation)} treatment which was on par with I_2 treatment (19.1) (DRIP irrigation 1.5 Epan in Raised bed system) and differed significantly with I_1 treatment (23.0) (DRIP irrigation 1.5 Epan in Flat bed system). While during 2021, significantly lowest sterility percentage was recorded with I_3 treatment (13.8) {Surface irrigation (up to saturation)} than I_2 treatment (19.1) (DRIP irrigation 1.5 Epan in Raised bed system) and I_1 treatment (21.9) (DRIP irrigation 1.5 Epan in Flat bed system) which in turn were on par with each other.

Higher nitrogen application with more number of splits especially during panicle initiation to flowering in LCC based nitrogen management might have elevated the number of filled grains per panicle and reduced chaffy grains formation [20]. These results are in accordance with findings of Prabhudev et al. [21] who opined that, application of nitrogen coinciding with flowering stage resulted in improvement of single seed weight and reduction in spikelet's sterility and increased recovery fraction of applied nitrogen with more splits under precision nitrogen management.

Testweight was not significantly influenced by irrigation and nitrogen management practices during both the years (Table 2). However, numerically highest testweight (21.6 and 21.5 g) was recorded with I_3 treatment {Surface irrigation (up to saturation)} while, lowest was recorded with I_1 treatment (DRIP irrigation 1.5 Epan in Flat bed system) (21.1 and 21.1 g) during 2020 and 2021 respectively. Similarly, under N management highest testweight was recorded with N_3 (LCC based N application) treatment (21.6 and 21.4 g) and lowest testweight (20.8 and 20.9 g) was registered with N_4 (No Nitrogen) during 2020 and 2021 respectively.

Interaction effect between irrigation and nitrogen management practices on yield attributes of aerobic rice was non significant during both the years. Higher yield attributes were observed under surface irrigation with LCC based nitrogen management followed by Raised bed drip irrigation with recommended practice of N application. This enhanced values of yield attributes might have contributed to higher growth parameters like plant height, total number of tillers, leaf area and total dry matter leading to higher photosynthetic rate and accumulation of more assimilates [22,23]. The optimum available soil moisture and increased root proliferation associated with more absorption of nutrients from soil solution under surface irrigation contributed to favourable growth attributes which in turn had resulted in higher yield attributes.

3.2 Effect of Precision Water and Nitrogen Management on Grain Yield of Aerobic Rice

The grain yield of aerobic rice as influenced by precision water and nitrogen management presented in Tables 3, 4 and 5 shows that, higher grain yield was recorded during 2021 than 2020 due to congenial weather conditions and crop sown 20 days earlier than first year.

Grain yield of aerobic rice was significantly influenced by irrigation and N management tools and their interaction during both the years (Table 3). Highest grain yield (3929 and 4413 kg ha^{-1}) under irrigation management was recorded with I_3 treatment {Surface irrigation (up to saturation)} which was on par with I_2 (DRIP irrigation 1.5 Epan in Raised bed system) (3625 and 3850 kg ha^{-1}) and differed significantly with I_1 treatment (DRIP irrigation 1.5 Epan in Flat bed system) (3227 and 3492 kg ha^{-1}) during both years. In general, the Nitrogen management treatments did not differ significantly among themselves with respect to grain yield, but were significantly superior over control (No Nitrogen). Highest grain yield (4091 and 4369 kg ha^{-1}) was recorded with N_3 (LCC based N application) treatment, while significantly lowest grain yield (2484 and 2731 kg ha^{-1}) was registered with N_4 (No Nitrogen) during 2020 and 2021 respectively.

It was evident from the Table 4 and 5 that, interaction effect between irrigation and nitrogen management practices on grain yield of aerobic rice was significant during both the years. Among all the interactions, highest grain yield was recorded with I_3N_2 (Surface irrigation with Green seeker based N application) (4524 and 5101 kg ha^{-1}) followed by I_3N_3 (Surface irrigation with LCC based N application) (4379 and 4830 kg ha^{-1}). While lowest was recorded with I_1N_4 (DRIP irrigation in Flat bed system with No Nitrogen application) (2319 and 2541 kg ha^{-1}) during 2020 and 2021 respectively.

Highest grain yield recorded with surface irrigation might be due to favourable vegetative growth and development as crop received sufficient moisture at critical stages and entire period of growth and maintained favourable soil water balance helped the crop to improve performance [24]. Relatively higher grain yield was recorded with raised bed under drip irrigation compared to flat bed method, which might be the resultant of higher nutrient uptake [25] wherein soil moisture was held at field capacity with uninterrupted and continuous moisture supply through drip, relatively less moisture loss and lower soil bulk density.

Among nitrogen management practices LCC and Greenseeker based nitrogen application had resulted in higher grain yields which might be due to precise nitrogen fertilization up to panicle initiation stage, that synchronized with the crop demand and enabled more uptake of nitrogen resulting in better vegetative growth, dry matter accumulation and higher yield attributes which lead to higher grain yield. These results were in conformity with the findings of Arpna and Arun, [26] and Baral et al. [27].

Table 1. Effect of Precision water and nitrogen management on yield attributes of Aerobic rice during *Rabi*, 2020 and 2021

	No. of panicles m^{-2}			Length of panicle (cm)			Panicle weight (g)		
Treatments	**2020**	**2021**	**Mean**	**2020**	**2021**	**Mean**	**2020**	**2021**	**Mean**
Vertical plots: Irrigation management (I)									
I_1	108	124	116	20.6	20.7	20.7	3.0	3.1	3.1
I_2	122	136	129	21.0	21.3	21.1	3.2	3.3	3.3
I_3	136	151	144	21.5	21.9	21.7	3.3	3.6	3.4
SE(m)±	4	5	4.1	0.75	0.8	0.8	0.1	0.2	0.1
CD (p=0.05)	14	18	16	NS	NS	NS	NS	NS	NS
Horizontal plots: Nitrogen management (N)									
N_1	136	150	143	21.4	21.5	21.5	3.3	3.4	3.4
N_2	132	146	139	21.2	21.4	21.3	3.2	3.3	3.3
N_3	140	157	148	21.6	21.9	21.7	3.4	3.5	3.5
N_4	79	96	87	20.0	20.4	20.2	2.8	3.0	2.9
SE(m)±	4	5	5	0.8	0.8	0.8	0.1	0.1	0.1
CD (p=0.05)	15	19	17	NS	NS	NS	NS	NS	NS
Interaction									
I×N									
SE(m)±	7	8	8	1.3	1.4	1.3	0.3	0.3	0.3
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
N×I									
SE(m)±	7	9	8	1.3	1.3	1.3	0.3	0.3	0.3
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

I_1: DRIP irrigation 1.5 Epan in Flat bed system, I_2: DRIP irrigation 1.5 Epan in Raised bed system, I_3: Surface irrigation (up to saturation)

N_1: Recommended practice (RDF)- (120:60:40 N P K kg ha^{-1}), N_2: Green seeker (Optical sensor) based N application, N_3: LCC based N application N_4: No Nitrogen

Table 2. Effect of Precision water and nitrogen management on yield attributes of Aerobic rice during *Rabi*, 2020 and 2021

	Filled grains panicle^{-1}			Total grains panicle^{-1}			Sterility percentage (%)			Test weight (g)		
Treatments	**2020**	**2021**	**Mean**	**2020**	**2021**	**Mean**	**2020**	**2021**	**Mean**	**2020**	**2021**	**Mean**
Vertical plots: Irrigation management (I)												
I_1	84.5	91.2	87.8	108.8	115.5	112.2	23.0	21.9	22.4	21.1	21.1	21.1
I_2	94.4	98.7	96.5	116.0	121.1	118.6	19.1	19.1	19.1	21.3	21.2	21.3
I_3	104.3	114.2	109.3	125.5	131.9	128.7	17.4	13.8	15.6	21.6	21.5	21.6
SE(m)±	2.4	2.7	2.5	3.1	3.1	3.0	0.6	0.7	0.2	0.76	0.8	0.8
CD (p=0.05)	9.6	10.7	9.7	12.4	12.0	11.7	2.3	2.9	0.6	NS	NS	NS
Horizontal plots: Nitrogen management (N)												
N_1	101.5	107.5	104.5	123.3	126.5	124.9	17.5	15.2	16.3	21.5	21.4	21.5
N_2	99.6	104.4	102.0	120.7	125.0	122.9	17.6	16.9	17.2	21.4	21.3	21.4
N_3	108.6	120.5	114.5	126.2	138.6	132.4	14.2	13.2	13.7	21.6	21.4	21.5
N_4	68.0	73.0	70.5	96.9	101.2	99.1	30.0	27.7	28.9	20.8	20.9	20.9
SE(m)±	4.0	5.5	4.7	4.4	6.6	5.4	0.4	0.6	0.5	0.8	0.8	0.8
CD (p=0.05)	13.9	18.9	16.2	15.1	22.8	18.7	1.4	2.2	1.7	NS	NS	NS
Interaction												
I×N												
SE(m)±	6.1	4.9	4.6	8.2	6.1	6.5	1.4	1.5	1.0	1.4	1.4	1.4
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
N×I												
SE(m)±	6.6	6.7	5.9	8.4	8.3	7.7	1.2	1.4	1.1	1.3	1.3	1.3
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

I_1: DRIP irrigation 1.5 Epan in Flat bed system, I_2: DRIP irrigation 1.5 Epan in Raised bed system. I_3: Surface irrigation (up to saturation)
N_1: Recommended practice (RDF)- (120:60:40 N P K kg ha^{-1}), N_2: Green seeker (Optical sensor) based N application, N_3: LCC based N application N_4: No Nitrogen

Table 3. Effect of Precision water and nitrogen management on Grain Yield of Aerobic rice during *Rabi*, 2020 and 2021

	Grain yield (kg ha^{-1})		
Treatments	**2020**	**2021**	**Mean**
Vertical plots: Irrigation management (I)			
I_1	3227	3492	3360
I_2	3625	3850	3738
I_3	3929	4413	4171
SE(m)±	132	162	144
CD (p=0.05)	518	638	566
Horizontal plots: Nitrogen management (N)			
N_1	3927	4325	4126
N_2	3873	4248	4061
N_3	4091	4369	4230
N_4	2484	2731	2608
SE(m)±	172	194	182
CD (p=0.05)	596	672	630
Interaction			
I×N			
SE(m)±	166	201	178
CD (p=0.05)	599	729	648
N×I			
SE(m)±	196	224	207
CD (p=0.05)	662	753	699

I_1: DRIP irrigation 1.5 Epan in Flat bed system, I_2: DRIP irrigation 1.5 Epan in Raised bed system, I_3: Surface irrigation (up to saturation)
N_1: Recommended practice (RDF)- (120:60:40 N P K kg ha^{-1}), N_2: Green seeker (Optical sensor) based N application, N_3: LCC based N application N_4: No Nitrogen

Table 4. Interaction effect of Precision water and nitrogen management on Grain Yield (kg ha^{-1}) of Aerobic rice during *Rabi*, 2020

Treatments	**Nitrogen management**				
Irrigation management	**N_1**	**N_2**	**N_3**	**N_4**	**Mean**
I_1	3702	3287	3600	2319	3227
I_2	3925	3809	4293	2475	3626
I_3	4153	4524	4379	2659	3929
Mean	3927	3873	4091	2484	
	I	N		I at same N	N at same I
SEm+	132	172		166	196
CD at p-0.05	518	596		599	662

*I_1: DRIP irrigation 1.5 Epan in Flat bed system, I_2: DRIP irrigation 1.5 Epan in Raised bed system, I_3: Surface irrigation **(**up to saturation)*
N_1: Recommended practice (RDF)- (120:60:40 N P K kg ha^{-1}), N_2: Green seeker (Optical sensor) based N application, N_3: LCC based N application, N_4: No Nitrogen

Table 5. Interaction effect of Precision water and nitrogen management on Grain Yield (kg ha^{-1}) of Aerobic rice during *Rabi*, 2021

Treatments	**Nitrogen management**				
Irrigation management	**N_1**	**N_2**	**N_3**	**N_4**	**Mean**
I_1	3965	3585	3878	2541	3492
I_2	4229	4058	4398	2714	3850
I_3	4781	5101	4830	2939	4413
Mean	4325	4248	4369	2731	

Treatments	**Nitrogen management**				
Irrigation management	N_1	N_2	N_3	N_4	**Mean**
	I	N		I at same N	N at same I
SEm+	162	194		201	224
CD at p-0.05	638	672		729	753

I_1: DRIP irrigation 1.5 Epan in Flat bed system, I_2: DRIP irrigation 1.5 Epan in Raised bed system, I_3: Surface irrigation (up to saturation)
N_1: Recommended practice (RDF)- (120:60:40 N P K kg ha^{-1}), N_2: Green seeker (Optical sensor) based N application, N_3: LCC based N application, N_4: No Nitrogen

4. CONCLUSION

In general, India's rice productivity is much below its potential in the farmers' field due to improper fertilizer and water application practices. The proper nutrient management, *i.e.,* the correct amount and timing of fertilizer application, minimizes the yield gap in rice crop. LCC and Greenseeker both have been proven to be effective in increasing rice yield. This study shows the potential to use different N management tools for rice growers to reduce N application without any yield penalty. Furthermore, growing aerobic rice with drip irrigation under raised bed system can be encouraged under dwindling water resources in the future.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. DES Statistics. Directorate of Economics and Statistics. Agricultural statistics at a glance-2020report; 2019-20 Available:https://eands.dacnet.nic.in/PDF/Agricultural%20Statistics%20at%20a%20Glance%20-%202020%20(English%20version).pdf
2. Season and Crop report. Telangana; 2016-17. Available:http://ecostat.telangana.gov.in/PDF /PUBLICATIONS/Season_crop_2009-10.pdf
3. Yadav JS. Conservation and managing water resource for sustainable agriculture. Journal of Water Management. 2002;10:1-2.
4. Matsunami M, Matsunami T, Kokubun M. Growth and yield of new rice for Africa (NERICAs) under different ecosystems and nitrogen levels. Plant Production Science. 2009;12(3):381-9.
5. Vishuddha N, Patel VK, Srivastav AK. Effect of land configuration and moisture regimes on productivity of hybrid maize (*Zea mays* L.) in summer season. International Journal of Plant & Soil Science. 2022;34(1):63-70.
6. Kusnarta IG, Mawaddah A, Dulur NW, Wangiyana W. The effect of organic waste application on some soil physical properties, growth and yield of red rice between conventional and aerobic irrigation system on raised-beds. In IOP Conference Series: Earth and Environmental Science. 2021;913(1): 012003. IOP Publishing.
7. Singh V, Singh B, Singh, Y, Thind HS, Gupta RK. Need based nitrogen management using the chlorophyll meter and leaf colour chart in rice and wheat in South Asia: a review. Nutrient Cycling in Agroecosystems. 2010;88(3):361-380.
8. Gupta RK, Shankar A, Bhatt R, Al-Huqail AA, Siddiqui MH, Kumar R. Precision nitrogen management in bt cotton (*Gossypium hirsutum*) improves seed cotton yield and nitrogen use efficiency, and reduces nitrous oxide emissions. Sustainability. 2022;14(4):2007.
9. Raun WR, Johnson GV. Improving nitrogen use efficiency for cereal production. Agronomy journal. 1999; 91(3):357-363.
10. Puneet sharma. Nitrogen management in rice using chlorophyll meter and GreenSeeker optical sensor. M. Sc. (Agri.) Thesis, Punjab Agriculural University. Ludhiana; 2011.
11. Bresler E. Trickle-drip irrigation: Principles and application to soil-water management. Advances in Agronomy. 1977;29:343-93.
12. Raun WR, Solie JB, Johnson GV, Stone ML, Mullen RW, Freeman KW, Thomason WE, Lukina EV Improving nitrogen use efficiency in cereal grain production with optical sensing and variable rate

application. Agronomy Journal. 2002; 94:815–820.
13. Kalyan J, Mondal R, Mallick GK. Growth, productivity and nutrient uptake of aerobic rice (*Oryza sativa* L.) as influenced by different nutrient management practices. Oryza. 2021;57(1):49-56.
14. Avijith S, Srivastava VK, Singh MK, Singh RK, Kumar S. Leaf colour chart vis-a-vis nitrogen management in different rice genotypes. American Journal of Plant Sciences. 2011;2(02):223-236.
15. Ramana MK, Rao AU, Visalakshmi V, Kumar KM. Evaluation of DRR leaf colour chart for rice varieties sown with drum seeder. Extended Summaries. 2020;467.
16. Duary S, Pramanik K. Response of aerobic rice to irrigation and nitrogen management in red and lateritic soil of West Bengal. Journal of Crop and Weed. 2019;15 (1):108-113.
17. Bhatta RD, Paudel M, Ghimire K, Dahal KR, Amgain LP, Pokhrel S, Acharya S, Kandel BP, Aryal K, KC B, Pandey M. Production and profitability of hybrid rice is influenced by different nutrient management practices. Agriculture. 2022;12(1):4.
18. Kato Y, Kamoshita A, Yamagishi J. Preflowering abortion reduces spikelet number in upland rice (*Oryza sativa* L.) under water stress. Crop Science. 2008;48(6):2389-95.
19. Anusha S, Nagaraju GB, Mallikarjun N, Gururaj K. Influence of drip irrigation scheduling on growth and yield of direct seeded aerobic rice (*Oryza sativa* L.). Ecoscan. 2015;9(1&2):329-332.
20. Anil K, Yakadri M, Jayasree G. Influence of nitrogen levels and times of application on growth parameters of aerobic rice. International Journal of Plant, Animal and Environmental Sciences. 2014;4(3):231-4.
21. Prabhudev DS, Nagaraju, Sheshadri T, Basavaraja PK, Timmegouda MN, Mallikarjuna GB. Precision management practices - a much needed set of agro-techniques to improve rice productivity and cutback the resources in aerobic rice condition under drip irrigation. International Journal of Current Microbiology and Applied Sciences. 2017;6(8):2800-2810.
22. Yoshida S. Fundamentals of Rice Crop Science. IRRI, Los Banos, Philippines: 269; 1981.
23. Ali MA, Ladha JK, Rickman J, Lales JS, Alam MM. Evaluation of drill seeding patterns and nitrogen management strategies for wet and dry land rice. Bangladesh Journal of Agricultural Research. 2012;37(4):559-571.
24. Kumar S, Kour S, Gupta M, Kachroo D, Singh H. Influence of rice varieties and fertility levels on performance of rice and soil nutrient status under aerobic conditions. Journal of Applied and Natural Science. 2017;9(2):1164-9.
25. Rekha B, Jayadeva HM, Kombali G, Nagaraju, Mallikarjuna, GB, Geethakumari A. Growth and yield of aerobic rice grown under drip fertigation. The Ecoscan. 2015; 9(1&2):435-437.
26. Arpna B, Arun K. Drip irrigation in rice and wheat cropping system under conservation agriculture: Water scarcity solution. Biological Forum. 2021;13(3b):89-93.
27. Baral BR, Pande KR, Gaihre YK, Baral KR, Sah SK, Thapa YB, Singh U. Real-time nitrogen management using decision support-tools increases nitrogen use efficiency of rice. Nutrient Cycling in Agroecosystems. 2021;119(3):355-368.

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