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Influence of alternate wetting and drying irrigation and nitrogen levels on grain quality, soil fertility, nutrient uptake in rice genotypes during *rabi* season

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Abstract
A field experiment was conducted on clay loam soil at Agricultural Research Institute, Rajendranagar, Hyderabad, Telangana during *rabi* seasons of 2016-17 and 2017-18 to identify optimum scheduling of alternate wetting and drying irrigation under different nitrogen levels on rice varieties. The treatments consisted of three irrigation regimes (recommended submergence of 2 to 5 cm water level, AWD irrigation when water level falls below 3cm from soil surface in perforated pipe, AWD irrigation when water level falls below 5cm from soil surface in perforated pipe) as main plot treatments, three nitrogen levels (120, 160 and 200 kg N ha^{-1}) as sub plot treatments and two rice varieties ('KNM-118' and 'JGL-18047') as sub-sub plot treatments laid out in split-split plot design with three replications. Protein content in the grain was not significantly influenced by irrigation regimes. Application of 200 kg N ha^{-1} (N_3) recorded significantly higher grain protein content which was on par with application of 160 kg N ha^{-1} (N_2). Significantly higher head rice recovery of rice was recorded with recommended submergence of 2 to 5 cm water level as per crop growth stage (I_1) over other irrigation regimes. Nitrogen levels did not influence the head rice recovery of rice. Recommended submergence of 2 to 5 cm water level as per crop growth stage (I_1) recorded significantly higher N uptake at panicle initiation and flowering stages which was at par with AWD irrigation of 5 cm when water level falls below 3 cm from soil surface in perforated pipe (I_2). The grain and straw uptake of N, P and K was higher with recommended submergence of 2 to 5 cm water level as per crop growth stage (I_1) and AWD irrigation of 5 cm when water level falls below 3 cm from soil surface in perforated pipe (I_2). Significantly higher grain and straw uptake of N, P and K was recorded with application of 200 kg N ha^{-1} (N_3). The post harvest soil status viz., pH, EC, organic carbon, bulk density and available soil nitrogen, phosphorus and potassium was not significantly influenced by irrigation regimes, nitrogen levels and varieties.

Keywords: Alternate wetting and drying irrigation, nitrogen levels, varieties, protein content, nutrient uptake, post harvest soil fertility

Introduction
Paddy (*Oryza sativa* L.) being the principal food crop to the billions of people around the World and India, occupies a pride place among the food crops cultivated in the world making a slogan "Rice is life" most appropriate. In India, it is grown in an area of 43.78 million hectare with a production and productivity of 225.51 million tonnes 5150 kg ha^{-1}, respectively. In India, Telangana State is a key rice producing state with 39.18 lakh hectares (Telangana State at a Glance, 2022) [11]. A huge amount of water is used for the rice irrigation under the conventional water management in lowland rice consuming about 70 to 80% of the total irrigated fresh water resources in the major part of the rice growing regions in Asia including India. Future predictions on water scarcity limiting agricultural production have estimated that by 2025, about 15-20 M ha of Asia's irrigated rice fields will suffer from water shortage in the dry season where flooded rice is the dominant cropping system. Therefore, rice could face a threat due to water shortage and hence, there is a need to develop and adopt water saving methods in rice cultivation so that production and productivity levels are elevated despite the looming water crisis. However, rice is very sensitive to water stress. Attempts to reduce water in rice production may result in reduction of yield and may threaten food security. The challenge is therefore to develop socially acceptable, economically viable and environmentally sustainable novel water management practices that allow rice production to be maintained or increased in the wake of declining water availability and an important water-saving technique is alternate wetting and drying (AWD).

This means that the rice fields are not kept continuously submerged, but are allowed to dry intermittently during crop growth period of rice. The underlying premise behind this irrigation technique is that the roots of the rice plant are still adequately supplied with water for some period even if there is currently no observable ponded water in the field. Among nutrients, nitrogen is the most important limiting element in rice growth (Jayanthi *et al*., 2007) [5]. Rice shows excellent response to nitrogen application, but the recovery of applied nitrogen is quite low approximately 31-40%. The practice of AWD results in periodic aerobic soil conditions, stimulating sequential nitrification and denitrification losses which could consequently lead to a greater loss of applied fertilizer and soil nitrogen compared with that under submergence conditions (Buresh and Haefele, 2010) [2]. Furthermore, if an interaction exists between water management practice and nitrogen rate, then the N input will have to be changed under AWD irrigation.

As for the relationship between irrigation regimes and protein, previous studies have suggested that the protein content of rice is higher and the nutritional quality of rice is improved under dry cultivation conditions or when the soil moisture content is low, but the cooking quality of rice is affected. Increasing N application significantly increased the crude protein content, chalky kernels rate and chalkiness of rice, and reduced the amylose content under the same irrigation mode, and water-saving irrigation significantly increased amylose content and chalkiness and reduced the crude protein content of rice at the same N level. But there are also studies suggested that different irrigation and fertilization treatments had no significant effect on amylose content of hybrid early rice, and had a significant effect on protein content. It is hypothesized that the water and nitrogen management of rice are reasonably coordinated, the yield, quality, water use efficiency and nitrogen use efficiency of rice can be improved, and the sustainable development of agriculture can be promoted. However, the evidence is very scarce in this regard. Systematic field research on agro-techniques such as nitrogen requirement for rice varieties under AWD irrigation is however limited. In this context, the present study is undertaken to evaluate the response of new rice varieties to levels of nitrogen under AWD during *rabi* season.

Materials and Methods

The study was conducted during *rabi* 2016-17 and 2017-18 on a clay loam soil at Agricultural Research Institute, Rajendranagar, Hyderabad. The experiment was laid out in split-split plot design with three replications with three irrigation regimes (recommended submergence of 2 to 5 cm water level as per crop growth stage, AWD irrigation of 5 cm when water level falls below 3cm from soil surface in perforated pipe, AWD irrigation of 5 cm when water level falls below 5cm from soil surface in perforated pipe) as main plot treatments and three nitrogen levels (120, 160 and 200 kg N ha^{-1}) as sub plot treatments and two rice varieties ('KNM-118' and 'JGL-18047') as sub-sub plot treatments. The seedlings were transplanted in the main field at 33 and 35 days age during *rabi* 2016-17 and *rabi* 2017-18, respectively, @ 2 seedlings per $hill^{-1}$. A crop geometry of 15 cm x 15 cm was adopted. The recommend dose of fertilizers *viz.*, 120, 160 and 200 kg N (as per sub plot treatments) + 26.4 kg P+33.3 K ha^{-1} was applied. Total nitrogen was applied in the form of urea in three equal splits *viz.*, 1/3rd as basal, 1/3rd at active tillering stage and 1/3rd at panicle initiation stage. The entire phosphorus was applied as basal in the form of single super phosphate, whereas, the potassium was applied in the form of muriate of potash in two equal splits *viz.*, as basal and top dressing at panicle initiation stage. The conventional flooding irrigation practice was followed in all the treatments till 15 DAT for proper establishment of the crop. The irrigation water was measured by water meter. After 15 DAT, the irrigation schedules were imposed as per the treatment requirement with the help of field water tube. In the present experiment, field water tubes were used to monitor and measure the depth of water level gradually receding in the field. When the field is flooded after each irrigation water application event, the water seeps through the perforations in to the field water tube and the water level inside the tube is the same as that of outside the tube. However, with time as the submergence depth of water level recedes, so also in the field water tube the same was monitored and measured in each field tube treatment-wise using a scale. Three different irrigation regimes based on receding water level were imposed using field tube. Irrigation was applied to re flood the field to a water depth of 5 cm when the water level in the field tube dropped to a threshold level of about 3 or 5 cm depending on the treatment during the base period. Irrigation was withheld 10 days ahead of harvest. The grain protein content (%) was determined according to AOAC (1994) [1] method. Head rice recovery (HRR) was calculated in percentage as:

$$\text{Head Rice Recovery (\%)} = \frac{\text{Weight of whole polished rice (g)}}{\text{Weight of paddy (g)}} \times 100$$

Five soil samples at 0 – 30 cm depth were collected initially at random in the experimental field before puddling and composite soil sample was obtained by quadrat method. Post-harvest soil samples were drawn at 0 – 30 cm treatment wise and air dried under shade and passed through 2 mm sieve and used for NPK analysis. The plant samples collected for dry matter estimation at tillering, panicle initiation. flowering and at harvest from the respective treatments were oven dried and finely ground and used for chemical analysis to estimate NPK content in the straw at respective stages and grain at harvest. Nitrogen content of shoot and grain at harvest was estimated by Modified Micro Kjeldhal's Method as outlined by Jackson (1967) [4] and expressed in percentage. Total phosphorus and potassium contents of whole plant at harvest were extracted by wet ashing method. The P content was estimated by Vanadomolybdate Yellow Colour Method (Jackson, 1967) [4] and K was determined by Photometeric Method (Jackson, 1967) [4]. The nitrogen, phosphorus and potassium uptake were estimated for each treatment separately using the following formulae:

$$\text{NPK uptake in grain} = \frac{\text{Nutrient content (\%) x Grain Yield (kg ha}^{-1})}{100}$$

$$\text{NPK uptake in straw (kg ha}^{-1}) = \frac{\text{Nutrient content (\%) x Straw Yield (kg ha}^{-1})}{100}$$

Results and Discussion

Protein content (%)

Irrigation regimes did not influence significantly the grain protein content of rice during *rabi* 2016-17, *rabi* 2017-18 and on pooled mean basis basis. However, numerically higher grain protein content was recorded with recommended submergence of 2-5 cm water level as per crop growth stage (I_1) (9.18, 9.14 and 9.16%). Significantly higher grain protein content was recorded with application of 200 kg N ha^{-1} (N_3) (9.20, 9.16 and 9.18%) which was at par with application of 160 kg N ha^{-1} (N_2) (9.16, 9.11 and 9.13%) and both were significantly superior as compared to application of 120 kg N ha^{-1} (N_1) (8.94, 8.90 and 8.92%) during *rabi* 2016-17, *rabi* 2017-18 and pooled mean basis, respectively. Nitrogen is an integral part of proteins and its increased application might have resulted in increased nitrogen content in paddy grains, which ultimately increased protein content in milled rice. Similar results were observed by Sandhu *et al*. (2015) [9]. The grain protein content of rice was not influenced significantly by varieties during the years *rabi* 2016-17, *rabi* 2017-18 and on pooled mean basis

Head rice recovery (%)

Irrigation maintained at recommended submergence of 2-5 cm water level as per crop growth stage (I_1) registered significantly higher head rice recovery i.e. 65.06, 65.12 and 65.09% over other irrigation regimes during *rabi* 2016-17, *rabi* 2017-18 and on pooled mean basis, respectively. Water stress in AWD treatments might have reduced head rice recovery by decreasing resistance of grains to abrasive milling process. Application of nitrogen at different levels did not influence significantly the head rice recovery during *rabi* 2016-17, *rabi* 2017-18 and on pooled mean basis. However, numerically higher head rice recovery was recorded with application of 200 kg N ha^{-1} (N_3) (64.23, 64.31 and 64.27%) during *rabi* 2016-17, *rabi* 2017-18 and pooled mean basis respectively. Similar results were observed by Singh *et al*. (2014) [10].

The head rice recovery of rice was not influenced significantly by varieties during the years *rabi* 2016-17, *rabi* 2017-18 and on pooled mean basis.

Nitrogen uptake (kg ha^{-1})

Among irrigation regimes, nitrogen uptake did not differ significantly at tillering during both the years of study. However, irrigation maintained at recommended submergence of 2-5 cm water level as per crop growth stage (I_1) (62.20 & 62.48 kg ha^{-1} and 104.32 & 106.29 kg ha^{-1}) and AWD irrigation of 5 cm when water level falls below 3 cm from soil surface in perforated pipe (I_2) (57.20 & 58.19 kg ha^{-1}, 100.71 & 102.62 kg ha^{-1}) were statistically at par with each other. This could be due to increased availability and efficient absorption of nutrients from the soil and transport of nutrients from roots to shoots and grains with irrigation maintained at recommended submergence of 2-5 cm water level as per crop growth stage (I_1) and AWD irrigation of 5 cm when water level falls below 3 cm from soil surface in perforated pipe (I_2). Similar results were observed by Rahaman and Sinha (2013) [8] and Kumar *et al*. (2014) [6]. However, significantly higher nitrogen uptake was recorded with irrigation maintained at recommended submergence of 2-5 cm water level as per crop growth stage (I_1) (86.93, 88.65 and 87.79 kg ha^{-1} in grain, and 40.96, 41.95 and 41.45 kg ha^{-1} in straw, 127.90, 130.60 and 129.25 kg ha^{-1} in total uptake during *rabi* 2016-17, *rabi* 2017-18 and on pooled mean basis respectively) and AWD irrigation of 5 cm when water level falls below 3 cm from soil surface in perforated pipe (I_2) (82.65, 86.86 and 84.76 kg ha^{-1} in grain, and 40.36, 41.77 and 41.06 kg ha^{-1} in straw, 123.01, 128.64 and 125.83 kg ha^{-1} in total uptake during *rabi* 2016-17, *rabi* 2017-18 and on pooled mean basis respectively) which were statistically at par with each other and both of these treatments had significantly higher nitrogen uptake than AWD irrigation of 5 cm when water level falls below 5 cm from soil surface in perforated pipe(I_3). Water stress caused by non-continuous irrigation not only affects the amount of used water but also, by reducing absorption of nutrients by plant and reduction of photosynthesis (Zumber *et al*., 2007) [12]. Nitrogen uptake was significantly higher with the application of 200 kg N ha^{-1} (N_3) (20.50, 60.91, 104.97 and 128.29 kg ha^{-1} at tillering, panicle initiation, flowering and at harvest on pooled mean basis, respectively) and was superior over application of 160 kg N ha^{-1} (N_2) and 120 kg N ha^{-1} (N_1). Similar trend of nitrogen uptake was found with application of 200 kg N ha^{-1} (N_3) in grain (86.48, 87.96 and 87.22 kg ha^{-1}) and in straw (40.89, 42.25 and 41.57 kg ha^{-1}) during both the years of study and on pooled mean basis. This might be due to nitrogen supply matches with the crop demand that led to higher uptake of nitrogen. These results are in tune with the findings of Duttarganvi *et al*. (2011) [3]. The nitrogen uptake of rice was not influenced significantly by varieties during the years *rabi* 2016-17, *rabi* 2017-18 and on pooled mean basis.

Phosphorus uptake (kg ha^{-1})

Irrigation maintained at recommended submergence of 2-5 cm water level as per crop growth stage (I_1) resulted in significantly higher phosphorous uptake during both the years of study *viz.*,24.65 in grain, 17.96 in straw and 42.62 kg ha^{-1} of total P uptake on pooled mean basis over AWD irrigation of 5 cm when water level falls below 3 cm from soil surface in perforated pipe (I_2) and AWD irrigation of 5 cm when water level falls below 5 cm from soil surface in perforated pipe (I_3). These results are in agreement with the findings of Rahaman and Sinha (2013) [8] and Kumar *et al*. (2014) [6]. Application of 200 kg N ha^{-1} (N_3) (23.88, 24.62 and 24.25 kg ha^{-1} during *rabi* 2016-17, *rabi* 2017-18 and on pooled mean basis, respectively) was superior in phosphorus uptake of grain over application of 120 kg N ha^{-1} (N_1) but was on par with the application of 160 kg N ha^{-1} (N_2). Phosphorus uptake in straw was significantly higher recorded with application of 200 kg N ha^{-1} (N_3) i.e., 17.25,17.73 and 17.49 kg ha^{-1} during *rabi* 2016-17, *rabi* 2017-18 and on pooled mean basis, respectively. The phosphorus uptake of rice was not influenced significantly by varieties during the years *rabi* 2016-17, *rabi* 2017-18 and on pooled mean basis.

Potassium uptake (kg ha^{-1})

Irrigation maintained at recommended submergence of 2-5 cm water level as per crop growth stage (I_1) resulted in significantly higher potassium uptake during both the years of study (34.35, 104.36 and 138.71 kg ha^{-1} on pooled mean basis in grain, straw and total uptake respectively) over AWD irrigation of 5 cm when water level falls below 3 cm from soil surface in perforated pipe (I_2) and AWD irrigation of 5 cm when water level falls below 5 cm from soil surface in perforated pipe (I_3). AWD irrigation of 5 cm when water level falls below 5 cm from soil surface in perforated pipe (I_3) might have affected some physiological processes such as transpiration rate which would decrease plant potassium uptake. Similar results were also observed by Rahaman and Sinha (2013) [8]. Application of 200 kg N ha^{-1} (N_3) was superior in potassium uptake of grain, straw and total uptake (33.98, 101.33 and 135.31 kg ha^{-1} on pooled mean basis, respectively) over application of 120 kg N ha^{-1} (N_1) and application of 160 kg N ha^{-1} (N_2) [1] in potassium uptake of grain, straw and total uptake on pooled mean basis, respectively). Pandey *et al*. (2009) [7] also reported similar results. The potassium uptake of rice was not influenced significantly by varieties during the years *rabi* 2016-17, *rabi* 2017-18 and on pooled mean basis

Post harvest soil status

pH, Electrical conductivity, organic carbon, bulk density, available phosphorus and available potassium were not significantly influenced by irrigation regimes, nitrogen levels and rice varieties during both the years of study and on pooled mean basis. While, Soil available nitrogen after harvest was significantly higher with application of 200 kg N ha^{-1} (N_3) during both the years of study. Application of 200 kg N ha^{-1} (N_3) recorded significantly higher available soil nitrogen (214.16 kg ha^{-1}) over application of 160 kg N ha^{-1} (N_2) (212.16 kg ha^{-1}) and with the application of 120 kg N ha^{-1} (N_1) (209.44 kg ha^{-1}) during *rabi* 2016-17. However, application of 200 kg N ha^{-1} (N_3) recorded significantly higher available soil nitrogen (215.66, 214.91 kg ha^{-1}) which was on par with application of 160 kg N ha^{-1} (N_2) (213.66, 212.91 kg ha^{-1}) and superior over the application of 120 kg N ha^{-1} (N_1) (210.44, 209.99 kg ha^{-1}) during *rabi* 2017-18 and on pooled mean basis, respectively. The irrigation regimes and varieties did not influence significantly available soil nitrogen after harvest during *rabi* 2016-17, *rabi* 2017-18 and on pooled mean basis.

Table 1: Protein content (%) and Head rice recovery (%) of rice as influenced by alternate wetting and drying irrigation, nitrogen levels and varieties during *rabi* 2016-17, *rabi* 2017-18 and pooled means

Treatments	Protein content (%)			Head rice recovery (%)		
	16-17	17-18	Pooled	16-17	17-18	Pooled
Irrigation regimes (I)						
I_1	9.18	9.14	9.16	65.06	65.12	65.09
I_2	9.07	9.04	9.06	63.85	63.87	63.91
I_3	9.03	8.98	9.01	63.32	63.34	63.33
S.Em±	0.04	0.05	0.04	0.20	0.23	0.21
C.D. at 5%	NS	NS	NS	0.57	0.64	0.60
Nitrogen levels (N)						
N_1-120 kg ha^{-1}	8.94	8.90	8.92	63.93	63.98	63.95
N_2-160 kg ha^{-1}	9.16	9.11	9.13	64.16	64.04	64.10
N_3-200 kg ha^{-1}	9.20	9.16	9.18	64.23	64.31	64.27
S.Em.±	0.04	0.04	0.04	0.14	0.16	0.15
C.D. at 5%	0.10	0.09	0.09	NS	NS	NS
Varieties (V)						
V_1 – KNM-118	9.10	9.06	9.08	64.17	64.21	64.19
V_2 – JGL-18047	9.10	9.05	9.07	64.04	64.01	64.03
S.Em.±	0.009	0.01	0.008	0.11	0.11	0.11
C.D. at 5%	NS	NS	NS	NS	NS	NS
Interactions (IxN, IxV, NxV, IxNxV)	NS	NS	NS	NS	NS	NS

I_1-Recommended submergence of 2-5 cm water level as per crop growth stage
I_2-AWD irrigation of 5 cm when water level falls below 3 cm from soil surface in perforated pipe
I_3-AWD irrigation of 5 cm when water level falls below 5 cm from soil surface in perforated pipe

Table 2: Nitrogen uptake (kg ha^{-1}) at different growth stages of rice as influenced by alternate wetting and drying irrigation, nitrogen levels and varieties during *rabi* 2016-17, *rabi* 2017-18 and pooled means

Treatments	Tillering			Panicle initiation			Flowering		
	16-17	17-18	Pooled	16-17	17-18	Pooled	16-17	17-18	Pooled
Irrigation regimes (I)									
I_1	19.14	20.26	19.70	62.20	62.48	62.34	104.32	106.29	105.24
I_2	18.54	20.18	19.36	57.20	58.19	57.69	100.71	102.62	101.67
I_3	18.18	19.82	19.00	55.09	55.94	55.51	96.78	98.69	97.73
S.Em±	0.27	0.22	0.23	1.84	1.55	1.69	1.31	1.35	1.29
C.D. at 5%	NS	NS	NS	5.12	4.32	4.69	3.65	3.76	3.59
Nitrogen levels (N)									
N_1-120 kg ha^{-1}	17.81	19.18	18.50	55.43	56.26	55.85	97.71	99.28	98.49
N_2-160 kg ha^{-1}	18.29	19.84	19.06	58.53	59.05	58.79	100.14	102.34	101.24
N_3-200 kg ha^{-1}	19.76	21.24	20.50	60.53	61.28	60.91	103.96	105.98	104.97
S.Em.±	0.42	0.27	0.32	0.88	0.94	0.90	0.77	0.72	0.73
C.D. at 5%	0.92	0.69	0.70	1.93	2.04	1.96	1.69	1.58	1.59
Varieties (V)									
V_1 – KNM-118	18.63	20.13	19.38	58.29	58.90	58.59	101.21	103.13	102.17
V_2 – JGL-18047	18.61	20.05	19.33	58.04	58.83	58.44	100.00	101.94	100.97
S.Em.±	0.28	0.28	0.26	0.43	0.42	0.40	0.67	0.69	0.65
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interactions (IxN, IxV, NxV, IxNxV)	NS	NS	NS	NS	NS	NS	NS	NS	NS

I_1-Recommended submergence of 2-5 cm water level as per crop growth stage
I_2-AWD irrigation of 5 cm when water level falls below 3 cm from soil surface in perforated pipe
I_3-AWD irrigation of 5 cm when water level falls below 5 cm from soil surface in perforated pipe

Table 3: Nitrogen uptake (kg ha^{-1}) at harvest of rice as influenced by alternate wetting and drying irrigation, nitrogen levels and varieties during *rabi* 2016-17, *rabi* 2017-18 and pooled means

Treatments	Nitrogen uptake at harvest (kg ha^{-1})								
	Grain			Straw			Total		
	16-17	17-18	Pooled	16-17	17-18	Pooled	16-17	17-18	Pooled
Irrigation regimes (I)									
I_1	86.93	88.65	87.79	40.96	41.95	41.45	127.90	130.60	129.25
I_2	82.65	86.86	84.76	40.36	41.77	41.06	123.01	128.64	125.83
I_3	77.50	83.28	80.39	35.46	36.65	36.05	115.96	119.93	117.95
S.Em±	1.69	0.74	1.19	0.24	0.41	0.29	1.78	1.09	1.42
C.D. at 5%	4.71	2.07	3.31	0.68	1.15	0.82	4.95	3.03	3.94
Nitrogen levels (N)									
N_1-120 kg ha^{-1}	81.04	84.70	82.87	36.58	37.78	37.18	117.62	122.48	120.05
N_2-160 kg ha^{-1}	82.56	86.13	84.34	39.31	40.33	39.82	122.88	126.47	124.67
N_3-200 kg ha^{-1}	86.48	87.96	87.22	40.89	42.25	41.57	126.37	130.21	128.29
S.Em.±	1.44	0.70	1.45	0.31	0.29	0.27	1.55	0.88	1.06
C.D. at 5%	3.14	1.53	2.31	0.69	0.63	0.59	3.39	1.93	2.32
Varieties (V)									
V_1 – KNM-118	84.36	86.75	85.56	38.92	40.03	39.48	123.29	126.78	125.04
V_2 – JGL-18047	82.35	85.78	84.07	38.93	40.21	39.57	121.29	126.00	123.64
S.Em.±	1.24	0.64	1.26	0.38	0.28	0.32	1.35	0.77	0.98
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interactions (IxN, IxV, NxV, IxNxV)	NS	NS	NS	NS	NS	NS	NS	NS	NS

I_1-Recommended submergence of 2-5 cm water level as per crop growth stage
I_2-AWD irrigation of 5 cm when water level falls below 3 cm from soil surface in perforated pipe
I_3-AWD irrigation of 5 cm when water level falls below 5 cm from soil surface in perforated pipe

Table 4: Phosphorus uptake (kg ha^{-1}) at harvest of rice as influenced by alternate wetting and drying irrigation and nitrogen levels and varieties during *rabi* 2016-17, *rabi* 2017-18 and pooled means

Treatments	Phosphorus uptake at harvest (kg ha^{-1})								
	Grain			Straw			Total		
	16-17	17-18	Pooled	16-17	17-18	Pooled	16-17	17-18	Pooled
Irrigation regimes (I)									
I_1	24.31	24.99	24.65	17.72	18.21	17.96	42.04	43.20	42.62
I_2	23.46	24.22	23.84	17.08	17.54	17.31	40.55	41.77	41.16
I_3	22.37	23.06	22.72	15.44	15.89	15.66	37.82	38.95	38.39
S.Em±	0.20	0.21	0.20	0.19	0.20	0.19	0.36	0.36	0.36
C.D. at 5%	0.56	0.60	0.57	0.54	0.55	0.55	1.00	1.01	0.99
Nitrogen levels (N)									
N_1-120 kg ha^{-1}	22.76	23.45	23.11	16.24	16.69	16.46	39.01	40.15	39.58
N_2-160 kg ha^{-1}	23.50	24.21	23.86	16.75	17.21	16.98	40.26	41.42	40.84
N_3-200 kg ha^{-1}	23.88	24.62	24.25	17.25	17.73	17.49	41.14	42.36	41.75
S.Em.±	0.20	0.22	0.20	0.11	0.12	0.11	0.27	0.28	0.27
C.D. at 5%	0.44	0.49	0.45	0.25	0.26	0.26	0.60	0.63	0.60
Varieties (V)									
V_1 – KNM-118	23.50	24.24	23.87	16.81	17.27	17.04	40.32	41.52	40.92
V_2 – JGL-18047	23.26	23.94	23.60	16.68	17.15	16.92	39.95	41.10	40.53
S.Em.±	0.17	0.18	0.17	0.14	0.14	0.14	0.28	0.28	0.28
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interactions (IxN, IxV, NxV, IxNxV)	NS	NS	NS	NS	NS	NS	NS	NS	NS

I_1-Recommended submergence of 2-5 cm water level as per crop growth stage
I_2-AWD irrigation of 5 cm when water level falls below 3 cm from soil surface in perforated pipe
I_3-AWD irrigation of 5 cm when water level falls below 5 cm from soil surface in perforated pipe

Table 5: Potassium uptake (kg ha^{-1}) at harvest of rice as influenced by alternate wetting and drying irrigation and nitrogen levels and varieties *rabi* 2016-17, *rabi* 2017-18 and pooled means

Treatments	Potassium uptake at harvest (kg ha^{-1})								
	Grain			Straw			Total		
	16-17	17-18	Pooled	16-17	17-18	Pooled	16-17	17-18	Pooled
Irrigation regimes (I)									
I_1	33.88	34.82	34.35	102.95	105.76	104.36	136.83	140.59	138.71
I_2	32.89	33.86	33.42	99.75	102.44	101.10	132.64	136.41	134.52
I_3	31.52	32.49	32.01	92.02	94.68	93.35	123.55	127.18	125.37
S.Em±	0.29	0.34	0.31	0.57	0.57	0.57	0.85	0.86	0.86
C.D. at 5%	0.82	0.95	0.86	1.60	1.59	1.59	2.38	2.40	2.38
Nitrogen levels (N)									
N_1-120 kg ha^{-1}	31.98	32.94	32.46	96.46	99.15	97.80	128.44	132.10	130.27
N_2-160 kg ha^{-1}	32.85	33.84	33.34	98.33	101.02	99.67	131.19	134.86	133.02
N_3-200 kg ha^{-1}	33.46	34.49	33.98	99.93	102.73	101.33	133.40	137.22	135.31
S.Em.±	0.22	0.26	0.23	0.51	0.52	0.52	0.68	0.70	0.69
C.D. at 5%	0.49	0.57	0.52	1.12	1.14	1.13	1.49	1.54	1.51
Varieties (V)									
V_1 – KNM-118	32.84	33.88	33.36	98.77	101.45	100.11	131.62	135.34	133.48
V_2 – JGL-18047	32.68	33.63	33.16	97.71	100.47	99.09	130.39	134.11	132.25
S.Em.±	0.24	0.25	0.24	0.56	0.55	0.55	0.77	0.74	0.75
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interactions (IxN, IxV, NxV, IxNxV)	NS	NS	NS	NS	NS	NS	NS	NS	NS

I_1-Recommended submergence of 2-5 cm water level as per crop growth stage
I_2-AWD irrigation of 5 cm when water level falls below 3 cm from soil surface in perforated pipe
I_3-AWD irrigation of 5 cm when water level falls below 5 cm from soil surface in perforated pipe

Table 6: Post harvest soil properties of rice as influenced by alternate wetting and drying irrigation and nitrogen levels and varieties during *rabi* 2016-17, *rabi* 2017-18 and pooled means

Treatments	pH			EC(ds m^{-1})			Organic carbon (%)			Bulk density(g cc^{-1})		
	16-17	17-18	Pooled	16-17	17-18	Pooled	16-17	17-18	Pooled	16-17	17-18	Pooled
Irrigation regimes (I)												
I_1	7.82	7.81	7.81	0.35	0.35	0.35	0.36	0.36	0.36	1.55	1.57	1.56
I_2	7.81	7.80	7.81	0.35	0.35	0.35	0.36	0.36	0.36	1.55	1.56	1.56
I_3	7.77	7.77	7.77	0.35	0.35	0.35	0.35	0.35	0.35	1.54	1.56	1.55
S.Em±	0.01	0.02	0.01	0.001	0.001	0.001	0.002	0.002	0.002	0.002	0.002	0.002
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Nitrogen levels (N)												
N_1-120 kg ha^{-1}	7.82	7.81	7.81	0.35	0.35	0.35	0.36	0.36	0.36	1.55	1.56	1.55
N_2-160 kg ha^{-1}	7.81	7.80	7.81	0.35	0.35	0.35	0.36	0.36	0.36	1.55	1.57	1.56
N_3-200 kg ha^{-1}	7.77	7.77	7.77	0.35	0.35	0.35	0.35	0.36	0.36	1.55	1.56	1.55
S.Em.±	0.02	0.02	0.01	0.001	0.001	0.001	0.002	0.005	0.003	0.002	0.005	0.004
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Varieties (V)												
V_1 – KNM-118	7.80	7.80	7.80	0.35	0.35	0.35	0.36	0.36	0.36	1.55	1.56	1.55
V_2 – JGL-18047	7.80	7.79	7.79	0.35	0.35	0.35	0.36	0.36	0.36	1.55	1.56	1.55
S.Em.±	0.01	0.01	0.01	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.001
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interactions (IxN, IxV, NxV, IxNxV)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Initial value	7.88	7.87		0.35	0.35		0.36	0.36		1.55	1.55	

I_1-Recommended submergence of 2-5 cm water level as per crop growth stage
I_2-AWD irrigation of 5 cm when water level falls below 3 cm from soil surface in perforated pipe
I_3-AWD irrigation of 5 cm when water level falls below 5 cm from soil surface in perforated pipe

Table 7: Available N, P_2O_5 and K_2O (kg ha^{-1}) in soil of rice as influenced by alternate wetting and drying irrigation, nitrogen levels and varieties during *rabi* 2016-17, *rabi* 2017-18 and pooled means

Treatments	Available N(kg ha^{-1})			Available P_2O_5(kg ha^{-1})			Available K_2O(kg ha^{-1})		
	16-17	17-18	Pooled	16-17	17-18	Pooled	16-17	17-18	Pooled
Irrigation regimes (I)									
I_1	210.88	212.22	211.55	43.73	44.04	43.88	348.83	355.05	351.94
I_2	211.22	212.55	211.88	43.17	43.48	43.33	349.50	355.50	352.50
I_3	213.66	215.00	214.33	43.21	43.52	43.36	349.94	355.94	352.94
S.Em±	1.60	1.60	1.60	0.37	0.37	0.37	1.33	1.39	1.36
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
Nitrogen levels (N)									
N_1-120 kg ha^{-1}	209.44	210.44	209.99	43.53	43.78	43.65	349.50	355.50	352.50
N_2-160 kg ha^{-1}	212.16	213.66	212.91	43.21	43.56	43.39	349.44	355.77	352.61
N_3-200 kg ha^{-1}	214.16	215.66	214.91	43.37	43.70	43,53	349.33	355.22	352.27
S.Em.±	0.86	1.20	1.00	0.32	0.31	0.31	1.45	1.59	1.50
C.D. at 5%	1.88	2.62	2.19	NS	NS	NS	NS	NS	NS
Varieties (V)									
V_1 – KNM-118	212.00	213.11	212.55	43.42	43.71	43.57	350.11	356.22	353.16
V_2 – JGL-18047	211.85	213.40	212.62	43.32	43.65	43.48	348.74	354.77	351.75
S.Em.±	0.97	1.05	0.98	0.20	0.19	0.19	0.66	0.69	0.63
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interactions (IxN, IxV, NxV, IxNxV)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Initial value	211	214		43	45		348	356	

I_1-Recommended submergence of 2-5 cm water level as per crop growth stage
I_2-AWD irrigation of 5 cm when water level falls below 3 cm from soil surface in perforated pipe
I_3-AWD irrigation of 5 cm when water level falls below 5 cm from soil surface in perforated pipe

Conclusion

It can be concluded that recommended submergence of 2-5 cm water level as per crop growth stage (I_1) or AWD irrigation of 5 cm when water level falls below 3 cm from soil surface in perforated pipe (I_2) with application of 160 kg N ha^{-1} can be adopted for superior quality parameters, nutrient uptake in both the rice varieties 'KNM-118' and 'JGL-18047' during *rabi* season.

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