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Physiological Response of Rice Genotypes under different Nitrogen Levels and Irrigation Regimes during *rabi* Season

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ABSTRACT: Growing rice under Alternate Wetting and Drying irrigation system is quite different from the conventional flood irrigation as it may lead to a greater loss of applied soil nitrogen compared to that under traditional submergence conditions. A field study was conducted during *rabi* 2016-17 and 2017-18 seasons at Agricultural Research Institute Main Farm, Rajendranagar, Hyderabad with an objective to study the effect of alternate wetting and drying irrigation regimes on rice genotypes under varied nitrogen levels. The study consisted of three irrigation regimes *viz*., (recommended submergence of 2 to 5 cm water level as per crop growth stage, Alternate Wetting and Drying irrigation of 5 cm when water level drops to 3cm in field water tube, Alternate Wetting and Drying irrigation of 5cm when water level drops to 5 cm in field water tube) which are main plot treatments and three levels of nitrogen (120, 160 and 200 kg N ha^{-1}) as sub plot treatments and two varieties of rice (KNM-118 and JGL-18047) as sub-sub plot treatments which were laid out in split-split plot design and replicated thrice. A significant improvement in the performance of physiological growth parameters of rice varieties was observed with irrigation regime recommended submergence of 2 to 5 cm water level as per crop growth stage which was on par with Alternate Wetting and Drying irrigation of 5 cm when water level drops to 3cm in field water tube. Higher physiological growth parameters of *Rabi* Rice varieties was reported with the application of 200 kg N ha^{-1} which was at par with application of 160 kg N ha^{-1}.

Keywords: Alternate wetting and drying irrigation regime, nitrogen levels, varieties, dry matter partitioning, SPAD, root length, root volume.

INTRODUCTION

Among the important staple food crops of the world, Rice (*Oryza sativa* (L.)) is a most prominent crop. Around 60-70 per cent of energy requirement of more than two billion people are met with rice and its derived products. India has the largest area under rice (43.50 m ha) and occupies second position in terms of production (163.51 m t) of rice with productivity of 3.76 t ha^{-1}, which is well below the average productivity of the world (4.51 t ha^{-1}) (www.ricestat.irri.org). Telangana is a predominant rice producing state of India, with 39.18 lakh hectares (Telangana State at a Glance, 2022). A large amount of water is required for irrigating the rice crop with the traditional practice in lowland rice as continuous deep flooding irrigation which depletes about 70 to 80 per cent of fresh water resources in the rice growing areas of Asia including India (Bouman and Tuong, 2001). Researchers have predicted that water scarcity for agriculture production in 15-20 million ha of rice area in Asia is looming large specifically during rabi season. Traditionally, rice crop requires about 3000-5000 litres of water to produce one kg of rice, whereas the same can be utilized to produce the double the quantities of cereals like maize or wheat. Hence, there is an urgent need to develop water saving technology in rice crop without affecting the productivity levels.

However, water stress in rice may cause reduction in yield as it is very sensitive to water. The water technologists have tested, advanced, applied and spread several water saving irrigation strategies in different rice ecologies. Aerobic rice is one such technology, having substantial water savings but also has penalty on grain yield. Alternate wetting and drying (AWD) is another important water-saving technique where water is let into the field after disappearance of ponded water and the rice fields are allowed to dry intermittently but not continuously submerged. The premise behind this irrigation technique is that there is adequate supply of water in the root zone of the rice plants for some period even if there is no observable ponded water in the field. The availability of water during the r*abi* season in Telangana is limited and hence, rice crop may be subjected to moisture stress where Alternate Wetting and Drying (AWD) is an appropriate irrigation water saving technology. A study reported an increase in paddy yield under AWD due to the increase of the proportion of productive tillers, reduction in the angle of the topmost leaves allowing more light penetration into the canopy, and change in shoot and root activity (Nisha and Samir 2021). A significant reduction in water input (26–29% in kharif and 22–27% in rabi season) could be achieved under AWD (Biswas *et al*., 2021). AWD is safe to apply in rice because it saves a lot of water (23.3 to 25.2 %) while just slightly reducing grain yield (Archana *et al*., 2022).

Nitrogen is the most important limiting major nutrient in rice growth (Jayanthi *et al*., 2007). Limitation of nitrogen in the growth period has a profound influence on dry matter accumulation which inturn affects grain filling increasing the number of unfilled grains. The recovery of applied nitrogen in rice is quite low (31-40%) though there is an excellent response to the applied nitrogen (Cassman *et al*., 2002). The chemical reaction of soil nitrogen under wet soil regimes of lowland rice is distinctly different from that under dry soil conditions. The technique of AWD results in frequent aerobic soil conditions, stimulating sequential nitrification and denitrification losses (Buresh and Haefele 2010). Hence, growing rice under such AWD irrigation system could ultimately lead to a greater loss of applied soil nitrogen compared to that under traditional submergence conditions. An optimal N rate and selection of critical growth stages for N application would be very effective for maximising yield and NUE under the water-saving cultivation technique of AWD irrigation.(Raquel *et al*, 2020). The mild soil water stress of 400 cm soil water potential and medium nitrogen of 120 kg N ha^{-1} practice reduces the irrigation water without any significant reduction in grain yield, and this combination of water and nutrient management will be more appropriate for sustainable rice production (Shekar *et al*., 2022). AWD recorded 4.5 % higher grain yield (6031kg ha^{-1}) as compared to conventional irrigation (5772 kg ha^{-1}) (Sudharani *et al.*, 2020). Compared with CF irrigation, mild AWD irrigation reduced the uptake of soil-derived N and aboveground biomass of rice but did not reduce rice yield. There may be an interaction between water and nitrogen to produce a coupling effect and hence, nitrogen input requirement have to be evaluated under AWD. The leaves, dry matter production, leaf area duration, leaf area index, root length, root volume, SPAD readings, dry matter partitioning are the prime physiological parameters which ultimately reflect the grain yield of rice. “Past research on alternate wetting and drying were centered on optimizing the depths and stages of rice for implementation. However, the studies on interaction of water and nitrogen levels and varietal response to alternate wetting and drying irrigation are lacking”. Under this background the present field experiment was undertaken to study the response of alternate wetting and drying irrigation regimes under different levels of nitrogen on performance of rice varieties.

MATERIALS AND METHODS

A field study was conducted during *rabi* 2016-17 and 2017-18 seasons at Agricultural Research Institute Main Farm, Rajendranagar, Hyderabad located geographically in Southern Telangana Zone of Telangana state. The soil of the experimental site was clay loam in texture, moderately alkaline in reaction to pH, non-saline in nature, low in organic carbon content, low in available nitrogen status, medium in available phosphorous status and potassium status. The statistical design of the experiment was split-split plot design with three replications where main plot treatments were irrigation regimes(3) I_1 (recommended submergence of 2 to 5 cm water level as per the crop growth stage, I_2 (AWD irrigation of 5 cm when water level drops below 3cm from soil surface in field water tube, I_3 (AWD irrigation of 5 cm when water level drops below 5cm from soil surface in field water tube) and three (3) levels of nitrogen (120, 160 and 200 kg N ha^{-1}) as sub plot treatments and two (2) rice varieties (‘KNM-118’ and ‘JGL-18047’) as sub-sub plot treatments. The age of the seedlings was 33 and 35 days age respectively during transplantation in the main field during *rabi* 2016-17 and *rabi* 2017-18, seasons. A spacing 15 cm x 15 cm was adopted. The fertilizer dosage was 120, 160 and 200 kg N ha^{-1} (as per sub plot treatments), 26.4 kg P, 33.3 K ha^{-1} was applied. The source of nitrogen was urea which was applied in three equal splits *viz.*, 1/3rd as basal, 1/3rd at active tillering stage and 1/3rd at panicle initiation stage and entire phosphorus fertilizer was applied as basal in the form of single super phosphate, and potassium was applied in the form of muriate of potash in two equal splits *viz.*, basal and at panicle initiation stage. The traditional continuous submergence irrigation practice was followed in all the treatments for proper establishment of the crop till 15 DAT. The applied irrigation water was measured by installed water meter. Later, the irrigation schedules were imposed as per the treatment with the help of perforated field water tube. In this present investigation, perforated field water tubes were used to monitor the depth of receding water level in the field. When the field is irrigated, the water seeps through the perforations in the field water tube and the level of water inside the perforated field tube is the same as that of outside. With the progress of time, depth of water level in the field gradually recedes, and so in the field water tube and the same was monitored in each field tube treatment-wise using a measuring scale. The different irrigation regimes based on drop in the water level were imposed using perforated field water tube. Irrigation water was applied to re flood the field level of water to a depth of 5 cm when the water level in the perforated field water tube drops to a threshold level of 3 or 5 cm as per the treatment. Irrigation was stopped 10 days before harvest. Leaf area duration (LAD) expresses the magnitude and persistence of leaf area during the crop growth period (Watson, 1947). Destructive sampling was followed for measurement of root length as cm. The root volume was measured by the displacement method using 500 ml measuring cylinder and root volume was measured as the volume of water displaced expressed in cc. The SPAD chlorophyll meter (SCMR) (SPAD) unit of Minolta Camera Company (SPAD 502) was used to measure SCMR values in rice at different stages of rice crop.

RESULTS AND DISCUSSION

Leaf area duration (dm^2 days). During *rabi* 2016-17, *rabi* 2017-18 and on pooled mean basis, data indicated that there was no significant difference in leaf area duration of rice due to irrigation regimes between 0-30 DAT. Markedly higher LAD between 30-60 DAT was recorded with recommended submergence of 2-5 cm water level as per crop growth stage (I_1) (77.05 dm^2 days) over other irrigation regimes during *rabi* 2016-17 and on pooled mean basis (77.77 dm^2 days) whereas there was no significant difference between recommended submergence of 2-5 cm water level as per crop growth stage(I_1) (78.49 dm^2 days) and AWD irrigation of 5 cm when water level drops below 3 cm from soil surface in perforated pipe (I_2) (77.65 dm^2 days) during *rabi* 2017-18. AWD irrigation of 5 cm when water level drops below 5 cm from soil surface in perforated pipe(I_3) (76.00, 77.04 and 76.52) has recorded lower LAD during *rabi* 2016-17, *rabi* 2017-18 and on pooled mean basis. Significantly higher LAD between 60-90 DAT was recorded with recommended submergence of 2-5 cm water level as per crop growth stage (I_1) (103.05, 103.59 and 103.32 dm^2 days respectively) over all other irrigation regimes during *rabi* 2016-17, *rabi* 2017-18 and on pooled mean basis. Significantly higher LAD between 90 days-harvest was recorded with recommended submergence of 2-5 cm water level as per crop growth stage (I_1) (23.84, 23.37 and 23.61 dm^2 days during *rabi* 2016-17, *rabi* 2017-18 and on pooled mean basis) which was on par with AWD irrigation of 5 cm when water level drops below 3 cm from soil surface in perforated pipe (I_2) (23.19, 22.75 and 22.97 dm^2 days. Moisture stress affected the growing plants which were unable to extract more water and nutrients from deeper layers of soil under moisture limited conditions which led to lower leaf area and thereby LAD. Nitrogen levels influenced significantly leaf area duration of rice between 0-30DAT, 30-60 DAT, and 60-90 DAT and was non significant between 90 DAT-harvest. Application of 200 kg N ha^{-1} recorded maximum leaf area duration (21.93, 22.58 and 22.25 dm^2 days between 0-30DAT, (77.15, 78.49 and 77.82 dm^2 days) between 30-60 DAT, 102.45, 103.19 and 102.82 dm^2 days between 60-90 DAT) during *rabi* 2016-17, *rabi* 2017-18 and on pooled mean basis respectively. Between 0-30 DAT and 60-90DAT leaf area duration recorded with 200 kg N ha^{-1} was similar with leaf area duration recorded with the application of 160 kg N ha^{-1}. Between 30-60 DAT, leaf area duration recorded with 200 kg N ha^{-1} was significantly higher than with 120 and 160 kg N ha^{-1} during *rabi* 2016-17 but was on par with 160 kg N ha^{-1} during *rabi* 2017-18. Lower leaf area duration between 0-30 DAT (20.88, 21.60 and 21.24 dm^2 days during *rabi* 2016-17, *rabi* 2017-18 and on pooled mean basis respectively), 30-60 DAT (75.65, 76.88 and 76.27 dm^2 days during *rabi* 2016-17, *rabi* 2017-18 and on pooled mean basis respectively), 60-90 DAT(100.60, 101.36 and 100.98 dm^2 days during *rabi* 2016-17, *rabi* 2017-18 and on pooled mean basis respectively) was recorded with 120 kg N ha^{-1}. Researchers such as Azarpour *et al.* (2014); Abid *et al*. (2015) also found increase in leaf area duration when levels of nitrogen increased. There was no significance in leaf area duration of rice between varieties during *rabi* 2016-17, *rabi* 2017-18 and on pooled mean basis.

Dry matter partitioning at harvest (g m^{-2}). There was no significant influence on partitioning of dry matter into leaves at harvest by irrigation regimes during *rabi* 2016-17 and *rabi* 2017-18 and on pooled mean basis. However, significant variation in dry matter partitioning into stem and panicles at harvest was found due to different irrigation regimes during *rabi* 2016-17, *rabi* 2017-18 and on pooled mean basis. There was no significant influence on dry matter accumulation in stem by irrigation regimes during *rabi* 2016-17, whereas during *rabi* 2017-18 and on pooled mean basis, significantly higher dry matter was accumulated in the stem with recommended submergence of 2-5 cm water level as per crop growth stage (I_1) (468.48, 463.58 g m^{-2}) which was at par with AWD irrigation of 5 cm when water level drops below 3 cm from soil surface in perforated field water tube (I_2) (463.56, 460.34 g m^{-2}). Lower dry matter was accumulated in stem due to AWD irrigation of 5 cm when water level drops below 5 cm from soil surface in perforated field water tube (I_3) (440.38, 458.58 g m^{-2}). Significantly higher dry matter was accumulated in the panicle with recommended submergence of 2-5 cm water level as per crop growth stage (I_1) (616.05, 617.04 and 616.54 g m^{-2} during *rabi* 2016-17, *rabi* 2017-18 and on pooled mean basis, respectively) which was at par with AWD irrigation of 5 cm when water level drops below 3 cm from soil surface in perforated field water tube (I_2) (597.27,604.67 and 600.97 g m^{-2} during *rabi* 2016-17, *rabi* 2017-18 and on pooled mean basis respectively). Lower dry matter was accumulated in the panicle with AWD irrigation of 5 cm when water level drops below 5 cm from soil surface in perforated pipe (I_3) (590.59, 590.51 and 590.55 g m^{-2} during *rabi* 2016-17, *rabi* 2017-18 and on pooled mean basis respectively). Similar to results reported by Biswas *et al*. (2021). At harvest, the dry matter partitioning into leaves and stem was not significantly influenced by nitrogen levels during *rabi* 2016-17 and *rabi* 2017-18 and on pooled mean basis. But at harvest, significant variation in dry matter partitioning into panicles was found between different levels of nitrogen during *rabi* 2016-17, *rabi* 2017-18 and on pooled mean basis. Application of 200 kg N ha^{-1} (N_3) has resulted in significantly higher dry matter accumulation in the panicle with (608.18, 610.26 and 609.22 g m^{-2} during *rabi* 2016-17, *rabi* 2017-18 and on pooled mean basis respectively) which was at par with 160 kg N ha^{-1} (N_2) (598.68,601.45 and 600.56 g m^{-2} during *rabi* 2016-17, *rabi* 2017-18 and on pooled mean basis respectively) and significantly superior over

120 kg N ha^{-1} (N_1). The increase in dry matter partitioning into panicles might be due to adequate and sufficient nitrogen in proper amount and at critical stages resulting in favorable vegetative growth and development as indicated in the plant height, leaf area index which contributed to higher dry matter production with increase in leaf photosynthetic activity. Application of 120 kg N ha^{-1} (N_1) resulted in lowest dry matter in the stem with (596.05, 600.50 and 598.27 g m^{-2} during *rabi* 2016-17, *rabi* 2017-18 and on pooled mean basis respectively) as reported by Ghosh *et al*. (2013); Krishna and Haefele (2013).Varieties did not significantly influence the dry matter partitioning of rice at harvest during the years *rabi* 2016-17, *rabi* 2017-18 and on pooled mean basis.

Root length (cm). Root length at tillering was not significantly influenced during *rabi* 2016-17 and *rabi* 2017-18 and on pooled mean basis. At panicle initiation, the highest root length was observed in the treatment AWD irrigation of 5 cm when water level drops below 3 cm from soil surface in perforated field water pipe (I_2) (27.14, 27.01 and 27.08 cm during *rabi* 2016-17, *rabi* 2017-18 and on pooled mean basis, respectively) followed by AWD irrigation of 5 cm when water level drops below 5 cm from soil surface in perforated field water pipe (I_3) (26.38, 26.41 and 26.40 cm during *rabi* 2016-17, *rabi* 2017-18 and on pooled mean basis, respectively) and the significantly lower root length was recorded during *rabi* 2016-17, *rabi* 2017-18 and on pooled mean basis, respectively) with recommended submergence of 2-5 cm water level as per crop growth stage (I_1) (25.43, 25.62 and 25.52 cm). At flowering, the highest root length was observed with AWD irrigation of 5 cm when water level drops below 3 cm from soil surface in perforated field water pipe (I_2) (30.12,30.27 and 30.20 cm during *rabi* 2016-17, *rabi* 2017-18 and on pooled mean basis, respectively) followed by AWD irrigation of 5 cm when water level drops below 5 cm from soil surface in perforated field water pipe (I_3) (29.12, 29.06 and 29.09 cm during *rabi* 2016-17, *rabi* 2017-18 and on pooled mean basis, respectively) and the significantly lower root length was recorded during *rabi* 2016-17, *rabi* 2017-18 and on pooled mean basis, respectively with recommended submergence of 2-5 cm water level as per crop growth stage (I_1) (28.65, 28.51 and 28.58 cm). At harvest, the highest root length was observed with AWD irrigation of 5 cm when water level drops below 3 cm from soil surface in perforated field water pipe (I_2)(26.96, 28.23 and 27.59 cm during *rabi* 2016-17, *rabi* 2017-18 and on pooled mean basis, respectively) followed by AWD irrigation of 5 cm when water level drops below 5 cm from soil surface in perforated field water pipe (I_3) (26.55, 27.86 and 27.20 cm during *rabi* 2016-17, *rabi* 2017-18 and on pooled mean basis, respectively) and significantly lower root length was recorded during *rabi* 2016-17, *rabi* 2017-18 and on pooled mean basis, respectively with recommended submergence of 2-5 cm water level as per crop growth stage (I_1) (26.03, 27.27 and 26.65 cm). The same trend in root length may be due to good aeration of soil that contributed to the improved root activity in alternate irrigation and drying regimes resulting in better root growth. This might be due to better soil aeration that contributed to the increased root activity in intermittent irrigation and better root growth were also found by Marimuthu *et al*. (2010); Dandeniya and Thies (2012).

Nitrogen levels have not significantly influenced the root length of rice at tillering and panicle initiation during *rabi* 2016-17 and *rabi* 2017-18 and on pooled mean basis. But significant variation in root length was found due to different levels of nitrogen at flowering and harvest during *rabi* 2016-17, *rabi* 2017-18 and on pooled mean basis. At flowering, 200 kg N ha^{-1} (N_3) (29.87, 29.71 and 29.79 cm recorded significantly higher root length during *rabi* 2016-17, *rabi* 2017-18 and on pooled mean basis respectively which was on par with 160 kg N ha^{-1} (N_2) (28.72, 28.83 and 28.78 cm during *rabi* 2016-17, *rabi* 2017-18 and on pooled mean basis, respectively) while lower root length was recorded with 120 kg N ha^{-1} (N_1) (28.30, 28.29 and 28.30cm during *rabi* 2016-17, *rabi* 2017-18 and on pooled mean basis respectively). At harvest, application of 200 kg N ha^{-1} (N_3) (26.80, 28.07 and 27.43 cm resulted in significantly higher root length during *rabi* 2016-17, *rabi* 2017-18 and on pooled mean basis respectively which was at par with 160 kg N ha^{-1} (N_2) (26.55, 27.79 and 27.17cm during *rabi* 2016-17, *rabi* 2017-18 and on pooled mean basis respectively) and lower root length was recorded with 120 kg N ha^{-1} (N_1) (26.20, 27.50 and 26.85cm during *rabi* 2016-17, *rabi* 2017-18 and on pooled mean basis respectively). The varieties did not significantly influence the root length of rice during *rabi* 2016-17, *rabi* 2017-18 and on pooled mean basis.

Root volume (cc hill^{-1}). Irrigation regimes failed to influence the root volume significantly at tillering during *rabi* 2016-17 and *rabi* 2017-18. At panicle initiation, flowering and harvest, AWD irrigation of 5 cm when water level drops below 3 cm from soil surface in perforated pipe (I_2) (37.52, 39.00 and 36.58 cc hill^{-1} on pooled mean basis, respectively) recorded significantly higher root volume which could be because of increase in activity of root oxidation and root source cytokinins in alternate wetting and drying irrigation which was in line with the findings of Marimuthu *et al*. (2010); Dandeniya and Thies (2012); Shekar *et al*. (2022). and the lowest root volume was observed at panicle initiation, flowering and at harvest with recommended submergence of 2-5 cm water level as per crop growth stage (I_1) (35.02, 35.83 and 34.51 cc hill^{-1}) which was at par with AWD irrigation of 5 cm when water level drops below 3 cm from soil surface in perforated field water pipe (I_2) (35.94, 36.90 and 35.13 cc hill^{-1}) on pooled mean basis respectively. The nitrogen levels could not influence the root volume of rice at tillering during both the years of study *viz.*, *rabi* 2016-17 and *rabi* 2017-18 and on pooled mean basis. But, significant difference in root volume was observed due to different levels of nitrogen at panicle initiation, flowering and harvest during *rabi* 2016-17, *rabi* 2017-18 and on pooled mean basis. At panicle initiation, 200 kg N ha^{-1} (N_3) (36.16, 37.11 and 36.63 cc hill^{-1}) recorded significantly higher root volume during *rabi* 2016-17, *rabi* 2017-18 and on pooled mean basis respectively) which was at par with 160 kg N ha^{-1} (N_2)

(35.74, 36.71 and 36.23 cc hill^{-1} during *rabi* 2016-17, *rabi* 2017-18 and on pooled mean basis respectively. Lower root volume was recorded with 120 kg N ha^{-1} (N_1) (35.33, 36.11 and 35.72 cc hill^{-1}) during *rabi* 2016-17, *rabi* 2017-18 and on pooled mean basis respectively). At flowering, 200 kg N ha^{-1} (N_3) (37.81, 37.47 and 37.56 cc hill^{-1} recorded significantly higher root volume during *rabi* 2016-17, *rabi* 2017-18 and on pooled mean basis respectively) which was on par with 160 kg N ha^{-1} (N_2) (37.49, 37.19 and 37.35 cc hill^{-1} during *rabi* 2016-17, *rabi* 2017-18 and on pooled mean basis respectively). Lower root volume was observed with 120 kg N ha^{-1} (N_1) (37.03, 36.51 and 36.77 cc hill^{-1} during *rabi* 2016-17, *rabi* 2017-18 and on pooled mean basis respectively). At harvest, 200 kg N ha^{-1} (N_3) (36.15, 35.40 and 35.77 cc hill^{-1} during *rabi* 2016-17, *rabi* 2017-18 and on pooled mean basis, respectively) recorded significantly higher root volume which was on par with 160 kg N ha^{-1} (N_2) (35.73, 35.11 and 35.45 cc hill^{-1} during *rabi* 2016-17, *rabi* 2017-18 and on pooled mean basis, respectively. Lowest root volume was recorded with 120 kg N ha^{-1} (N_1) (35.29, 34.74 and 35.03 cc hill^{-1} during *rabi* 2016-17, *rabi* 2017-18 and on pooled mean basis, respectively).The root volume of rice during the years *rabi* 2016-17, *rabi* 2017-18 and on pooled mean basis was not influenced significantly by varieties.

Table 1: Leaf area duration (dm^2 days) of rice varieties as influenced by alternate wetting and drying irrigation, nitrogen levels and varieties during *rabi* 2016-17, *rabi* 2017-18 and pooled means.

Treatments	Leaf area duration (dm^2 days)											
	0-30 DAT			30-60DAT			60-90DAT			90-Harvest		
	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	21.58	22.24	21.91	77.05	78.49	77.77	103.05	103.59	103.32	23.84	23.37	23.61
I_2	21.45	22.20	21.82	76.37	77.65	77.01	101.66	102.38	102.02	23.19	22.75	22.97
I_3	21.50	22.21	21.85	76.00	77.04	76.52	99.54	100.64	100.09	21.75	21.60	21.68
S.Em±	0.11	0.20	0.15	0.12	0.35	0.15	0.45	0.22	0.28	0.44	0.42	0.42
C.D. at 5%	NS	NS	NS	0.35	0.98	0.42	1.25	0.61	0.78	1.22	1.17	1.16
Nitrogen levels (N)												
N_1-120 kg ha^{-1}	20.88	21.60	21.24	75.65	76.88	76.27	100.60	101.36	100.98	22.35	21.96	22.16
N_2-160 kg ha^{-1}	21.71	22.47	22.09	76.62	77.82	77.22	101.20	102.05	101.63	22.85	22.67	22.76
N_3-200 kg ha^{-1}	21.93	22.58	22.25	77.15	78.49	77.82	102.45	103.19	102.82	23.59	23.08	23.33
S.Em.±	0.14	0.13	0.13	0.20	0.34	0.24	0.54	0.56	0.50	0.50	0.51	0.46
C.D. at 5%	0.31	0.29	0.30	0.45	0.75	0.53	1.18	1.22	1.09	NS	NS	NS
Varieties (V)												
V_1 – KNM-118	21.56	22.24	21.90	76.51	77.75	77.13	101.68	102.33	101.88	23.06	22.79	22.92
V_2 – JGL-18047	21.46	22.20	21.83	76.45	77.71	77.08	101.15	102.07	101.74	22.79	22.35	22.71
S.Em.±	0.06	0.09	0.07	0.11	0.17	0.12	0.43	0.43	0.41	0.45	0.43	0.43
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

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 drops below 3 cm from soil surface in perforated pipe
I_3-AWD irrigation of 5 cm when water level drops below 5 cm from soil surface in perforated pipe

Table 2: Dry matter partitioning (g m^{-2}) 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	Dry matter accumulation at harvest (g m^{-2})								
	Leaf			Stem			Panicle		
	16-17	17-18	Pooled	16-17	17-18	Pooled	16-17	17-18	Pooled
Irrigation regimes (I)									
I_1	221.11	227.28	224.20	458.67	468.48	463.58	616.05	617.04	616.54
I_2	226.72	236.04	231.38	457.11	463.56	460.34	597.27	604.67	600.97
I_3	219.12	212.93	216.03	447.57	440.38	458.58	590.59	590.51	590.55
S.Em±	6.51	6.93	5.68	5.33	6.14	4.53	6.76	5.90	3.15
C.D. at 5%	NS	NS	NS	NS	17.06	12.60	18.78	16.39	16.75
Nitrogen levels (N)									
N_1-120 kg ha^{-1}	223.78	225.43	224.61	454.00	454.99	454.50	596.05	600.50	598.27
N_2-160 kg ha^{-1}	223.09	227.71	225.40	454.31	457.62	455.96	598.68	601.45	600.56
N_3-200 kg ha^{-1}	220.09	223.12	221.60	455.03	459.82	457.43	608.18	610.26	609.22
S.Em.±	3.22	1.94	1.82	3.01	2.04	1.58	4.15	3.53	2.98
C.D. at 5%	NS	NS	NS	NS	NS	NS	9.04	7.71	7.49
Varieties (V)									
V_1 – KNM-118	222.78	215.68	224.23	454.07	457.31	455.69	602.88	604.20	603.54
V_2 – JGL-18047	221.86	215.16	223.51	454.82	457.64	456.23	599.72	603.94	601.83
S.Em.±	3.07	2.67	2.63	2.84	2.66	2.49	4.04	4.06	3.54
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 drops below 3 cm from soil surface in perforated pipe
I_3-AWD irrigation of 5 cm when water level drops below 5 cm from soil surface in perforated pipe

SPAD readings. The SPAD reading values showed no significance due to irrigation regimes at 15 and 30 DAT but were significantly different at 45 and 60 DAT during *rabi* 2016-17 and *rabi* 2017-18. Recommended submergence of 2-5 cm water level as per crop growth stage (I_1) recorded higher readings at 45 DAT(37.95, 37.67 and 37.81) and at 60 DAT (39.13, 39.21 and 39.17), during *rabi* 2016-17, *rabi* 2017-18 and on pooled mean basis respectively which were at par with AWD irrigation of 5 cm when water level drops below 3 cm from soil surface in perforated field water pipe (I_2) readings at 45 DAT (36.16, 36.78 and 36.47) and (38.12, 37.74 and 37.99) at 60 DAT, but these were found significantly higher as compared to AWD irrigation of 5 cm when water level drops below 5 cm from soil surface in perforated field water pipe (I_3) at 45 DAT (34.32, 34.45 and 34.39) and at 60 DAT (35.47, 36.18 and 35.83), during *rabi* 2016-17, *rabi* 2017-18 and on pooled mean basis, respectively as reported by Nisha and Samir (2021). The superior SPAD reading values could be attributed to increase in the uptake of nitrogen due to reduced leaching losses in conventional flood irrigation regime over deficit irrigated regimes (Aulakh and Singh 1997).

Table 3: Root length (cm) 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	Root length (cm)											
	Tillering			Panicle Initiation			Flowering			Harvest		
	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	16.66	16.68	16.67	25.43	25.62	25.52	28.65	28.51	28.58	26.03	27.27	26.65
I_2	16.87	16.81	16.84	27.14	27.01	27.08	30.12	30.27	30.20	26.96	28.23	27.59
I_3	17.02	17.01	17.01	26.38	26.41	26.40	29.12	29.06	29.09	26.55	27.86	27.20
S.Em±	0.12	0.14	0.12	0.36	0.36	0.31	0.38	0.39	0.38	0.11	0.16	0.12
C.D. at 5%	NS	NS	NS	1.00	1.00	0.87	1.07	1.08	1.08	0.33	0.44	0.34
Nitrogen levels (N)												
N_1-120 kg ha^{-1}	16.78	16.74	16.76	26.24	26.32	26.28	28.30	28.29	28.30	26.20	27.50	26.85
N_2-160 kg ha^{-1}	16.81	16.82	16.81	26.25	26.33	26.29	28.72	28.83	28.78	26.55	27.79	27.17
N_3-200 kg ha^{-1}	16.96	16.93	16.95	26.46	26.40	26.43	29.87	29.71	29.79	26.80	28.07	27.43
S.Em.±	0.08	0.18	0.10	0.10	0.18	0.10	0.30	0.27	0.27	0.18	0.18	0.17
C.D. at 5%	NS	NS	NS	NS	NS	NS	0.65	0.60	0.60	0.39	0.40	0.38
Varieties (V)												
V_1 – KNM-118	16.85	16.91	16.88	26.38	26.39	26.38	29.34	29.42	29.38	26.53	27.88	27.20
V_2 – JGL-18047	16.85	16.75	16.80	26.25	26.31	26.28	29.25	29.13	29.19	26.49	27.70	27.09
S.Em.±	0.05	0.09	0.05	0.15	0.22	0.09	0.23	0.25	0.23	0.20	0.16	0.17
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

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 drops below 3 cm from soil surface in perforated pipe
I_3-AWD irrigation of 5 cm when water level drops below 5 cm from soil surface in perforated pipe

Table 4: Root volme (cc hill^{-1}) 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	Root volume (cc hill^{-1})											
	Tillering			Panicle Initiation			Flowering			Harvest		
	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	20.11	20.26	20.19	34.60	35.45	35.02	36.46	35.48	35.83	34.92	34.09	34.51
I_2	20.38	20.37	20.38	37.11	37.93	37.52	38.41	39.60	39.00	36.50	36.66	36.58
I_3	19.98	20.01	20.00	35.52	36.36	35.94	37.60	36.20	36.90	35.75	34.50	35.13
S.Em±	0.15	0.14	0.10	0.43	0.44	0.44	0.45	0.41	0.39	0.42	0.42	0.38
C.D. at 5%	NS	NS	NS	1.20	1.24	1.22	1.26	1.15	1.09	1.17	1.19	1.06
Nitrogen levels (N)												
N_1-120 kg ha^{-1}	20.10	20.12	20.11	35.33	36.11	35.72	37.03	36.51	36.77	35.29	34.74	35.03
N_2-160 kg ha^{-1}	20.15	20.17	20.16	35.74	36.71	36.23	37.49	37.19	37.35	35.73	35.11	35.45
N_3-200 kg ha^{-1}	20.24	20.34	20.29	36.16	37.11	36.63	37.81	37.47	37.56	36.15	35.40	35.77
S.Em.±	0.06	0.13	0.07	0.19	0.21	0.19	0.15	0.18	0.11	0.22	0.20	0.15
C.D. at 5%	NS	NS	NS	0.42	0.47	0.41	0.33	0.39	0.25	0.49	0.45	0.44
Varieties (V)												
V_1 – KNM-118	20.17	20.28	20.22	35.85	36.70	36.28	37.52	37.16	37.34	35.82	35.14	35.48
V_2 – JGL-18047	20.15	20.15	20.15	35.63	36.45	36.04	37.32	36.98	37.15	35.62	35.02	35.32
S.Em.±	0.09	0.07	0.07	0.11	0.12	0.11	0.17	0.20	0.15	0.17	0.16	0.14
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

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 drops below 3 cm from soil surface in perforated pipe
I_3-AWD irrigation of 5 cm when water level drops below 5 cm from soil surface in perforated pipe

The nitrogen levels failed to influence SPAD readings in rice by at 15 DAT during the years *rabi* 2016-17, *rabi* 2017-18 and on pooled mean basis. At 30 DAT, significantly higher SPAD readings were reported with application of 200 kg N ha^{-1} (N_3) (36.65, 36.90 and 36.71 during *rabi* 2016-17, *rabi* 2017-18 and on pooled mean basis, respectively) when compared to application of 120 kg N ha^{-1} (N_1) (35.54, 35.69 and 35.62) and 160 kg N ha^{-1} (N_2) (35.99, 36.14 and 36.06 during *rabi* 2016-17, *rabi* 2017-18 and on pooled mean basis, respectively). At 45 DAT, higher SPAD readings (37.01, 37.55 and 37.28 during *rabi* 2016-17, *rabi* 2017-18 and on pooled mean basis, respectively) were observed with application of 200 kg N ha^{-1} (N_3) when compared to application of 120 kg N ha^{-1} (N_1) (35.97, 35.84 and 35.90) and 160 kg N ha^{-1} (N_2) (36.46, 36.52 and 36.49 during *rabi* 2016-17, *rabi* 2017-18 and on pooled mean basis, respectively). The same trend was reported at 60 DAT. Similar results were reported by Khalifa (2012). There was no difference in SPAD readings in rice between varieties during the years *rabi* 2016-17, *rabi* 2017-18 and on pooled mean basis.

Table 5: SPAD chlorophyll meter readings 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	15 DAT			30DAT			45DAT			60DAT		
	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	33.87	34.14	34.00	36.02	36.36	36.19	37.95	37.67	37.81	39.13	39.21	39.17
I_2	34.32	34.33	34.27	36.22	36.27	36.19	36.16	36.78	36.47	38.12	37.74	37.99
I_3	33.91	34.12	33.96	35.94	36.10	36.02	34.32	34.45	34.39	35.47	36.18	35.83
S.Em±	0.26	0.23	0.21	0.09	0.10	0.09	0.48	0.52	0.33	0.37	0.39	0.34
C.D. at 5%	NS	NS	NS	NS	NS	NS	1.33	1.44	0.83	1.04	1.09	0.97
Nitrogen levels (N)												
N_1-120 kg ha^{-1}	33.67	33.99	33.83	35.54	35.69	35.62	35.97	35.84	35.90	36.98	37.23	37.10
N_2-160 kg ha^{-1}	33.92	34.18	34.05	35.99	36.14	36.06	36.46	36.52	36.49	37.51	37.66	37.58
N_3-200 kg ha^{-1}	34.51	34.42	34.35	36.65	36.90	36.71	37.01	37.55	37.28	38.24	38.25	38.25
S.Em.±	0.33	0.16	0.21	0.30	0.29	0.25	0.21	0.23	0.12	0.22	0.29	0.23
C.D. at 5%	NS	NS	NS	0.65	0.64	0.56	0.47	0.50	0.28	0.48	0.65	0.51
Varieties (V)												
V_1 – KNM-118	34.18	34.21	34.16	36.07	36.28	36.17	36.50	36.81	36.66	37.64	37.88	37.76
V_2 – JGL-18047	33.88	34.19	34.00	36.05	36.21	36.09	36.45	36.46	36.46	37.57	37.54	37.52
S.Em.±	0.21	0.16	0.14	0.16	0.18	0.08	0.12	0.17	0.10	0.27	0.24	0.24
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

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 drops below 3 cm from soil surface in perforated pipe
I_3-AWD irrigation of 5 cm when water level drops below 5 cm from soil surface in perforated pipe

CONCLUSION

From the observations of the present study, AWD irrigation of 5 cm when water level drops below 3 cm from soil surface in perforated pipe (I_2) with application of 160 kg N ha^{-1} in either of varieties JGL-18047 and KNM-118 is needed for superior performance in terms of physiological parameters like leaf area duration, dry matter partitioning, SPAD readings in rice.

FUTURE SCOPE

The performance of mechanized rice under AWD irrigation and evaluation of nitrogen dynamics in the soil under AWD irrigation system.

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Conflict of Interest. None.

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