Original Research Article

Phenology and nutrient studies of rice (*Oryza sativa* L.) as influencedby different crop establishment methods and irrigation scheduling

Abstract

The investigation on influence of different crop establishment methods and irrigation scheduling on phenology and nutrient studies of rice (*Oryza sativa* L.) was carried out in sandy clay soils at Agriculture Research Station, Kampasagar, Nalgonda district for two *kharif* seasons of 2021 & 2022. The experiment was laid out in split plot design with three main plots and 3 sub-plots replicated thrice. Phenological parameters like days to 50 % flowering and maturity has a significantimpact among establishment methods in which dry direct seeded rice with drum seeder (M_1) recorded less number of days compared to manual transplanted puddled rice (M_3). Total nitrogen, phosphorus and potassium content was non significantly increased with wet seeded rice with drum-seeder (M_2) followed by manual transplanted puddled rice (M_3) and dry direct seeded rice with seed drill (M_1) method.In contrast to above mentioned nutrient content, uptakes has shown significant difference among establishment methods. However, irrigation scheduling treatments and interaction effect has found to be non-significant for both the years of study. In comparison from first year study, second year recorded higher values which may be due to better favourable condition that attributed better performance of crop.

Key words: Phenology, alternate wetting and drying, dry direct seeded rice, nutrient uptake and establishment methods

Introduction

Rice (*Oryza sativa* L.) holds a pivotal role as a staple food for over half of the world's population, particularly in developing countries where it serves as both a dietary mainstay and an economic backbone (Sridhar*et al.*, 2022). The global importance of rice is underscored by its significant contribution to food security and agricultural livelihoods. In the 2024-25 period, China emerged as the top producer of paddy rice, yielding 145.3 million metric tonnes, closely followed by India with 145.00 million metric tonnes (WAP, 2025).

Within India, rice cultivation spans approximately 50 million hectares, achieving an average productivity of 4.35 tonnes per hectare (DES, 2025). Telangana, a key rice-producing state, demonstrated notable performance during the *kharif* (*Vanakalam*) season, with rice cultivation covering 26.3 lakh hectares. The state's paddy production reached 15.3 million metric tonnes, with an impressive productivity of 5.2 tonnes per hectare (GoT, 2024).

Despite these achievements, the escalating demand for rice production poses sustainability challenges, particularly in the face of diminishing water resources and climate variability. Addressing these concerns requires innovative agricultural practices that balance productivity with environmental stewardship.

To address this challenge, alternative water-saving rice production techniques, such as Direct Seeded Rice (DSR) either sprouted or dry seeds sown directly in soil by using seed drill or drum seeder are gaining attention. DSR offers several advantages over conventional puddled transplanted rice (PTR), including reduced water usage, labour savings, improved soil structure, and lower greenhouse gas emissions (Kaur *et al.* 2024). DSR helps to optimize water use while maintaining comparable yields. Given the pressing need for sustainable rice production, exploring efficient crop establishment methods and irrigation practices is essential for ensuring food security and environmental sustainability in the coming decades (Kumar *et al*., 2018).

Rice is highly sensitive to water stress, making it challenging to balance water conservation with maintaining high yields. One such promising technique is Alternate Wetting and Drying (AWD), also known as intermittent irrigation. AWD involves applying water to the fields several days after the visible ponded water has disappeared, allowing the fields to dry intermittently during the rice growth period. The underlying principle of AWD is that rice plant roots can access sufficient moisture even when there is no visible standing water in the field. This intermittent drying does not induce water stress in the plants but significantly reduces water usage. Singh *et al*. (2015) reported that, in India, AWD can reduce water use by 40–70% compared to continuous flooding methods, without causing a significant reduction in yield. This makes AWD a highly effective and sustainable irrigation technique that can help address the growing water scarcity issues while safeguarding rice production.AWD is one which saves water to the extent of 20-50 per cent compared to farmers practice of continuous flooding (Avil Kumar and Rajitha, 2019).

Nitrogen (N), Phosphorus (P) and Potassium (K) are essential macronutrients that play a critical role in plant growth and development. Nitrogen is vital for chlorophyll production and promotes vigorous vegetative growth, influencing leaf size and colour.

Phosphorus supports root development, energy transfer, and flowering, while potassium enhances water regulation, enzyme activation, and improves overall plant resilience to stress. The balanced application of NPK not only boosts crop yield and quality but also enhances nutrient use efficiency, contributing to sustainable agricultural practices (Lathwal*et al*. 2024). Understanding their importance is key to optimizing plant health and maximizing productivity in modern farming systems.

Keepingthese facts in view, the present investigationwas carried out to study the behaviour of irrigation regimes under different establishment methods.

Materials and methods

The field experiment was conducted during *kharif* seasons of 2021 and 2022 at the Agriculture Research Station, Kampasagar, Nalgonda district of Telangana state. The farm is geographically situated in the southern part of Telangana at 16^{0}51'9.559" N latitude and 79°28'26.581"E longitude at an altitude of 126.93 m above mean sea level and falls under Southern Telangana Agro-climatic Zone (STZ) of Telangana.The experimental field was sandy clay in texture with a pH of 8.0 and EC of 0.27 dS m^{-1}, low in organic carbon (0.41%) and available nitrogen (237.7 kg ha^{-1}), high in available phosphorus (27.1 kg ha^{-1}) and potassium (369.3 kg ha^{-1}). The variety used for the study was KNM-118 which contains 118-120 days duration. The experiment was laid out in split- plot design with three different rice establishment methods as main plot treatments *viz.*, Dry direct seeding with seed drill (M_1-DDSR), Wet direct seeding with drum seeder (M_2-WDSR) and manual transplanting (M_3-TPR) and three irrigation treatments as sub-plots *viz.*, Continuous submergence (I_1-CS), Maintaining saturation after disappearance of ponded water (I_2-Saturation) and Alternate Wetting and Drying Irrigation (AWDI) of 5 cm when water level in pipe falls 5 cm below surface (I_3). The experimental field was provided with irrigation channels, buffer channels and the individual plots were demarcated by bunds. Each plot was bounded by 0.2 m high earthen bunds with polythene sheet lining which extended from the top of the bund to a depth of 0.5 m below the soil surface to minimize lateral movement of water through and below the bunds. There was also a 1 m wide buffer between all plots to further reduce the possibility of interference between plots. The irrigation water measured with the help of water meter. Main field was ploughed twice with cultivator and rotavator to obtain fine tilth. In DDSR sowing rice seeds was done using a tractor-drawn seed drill @ 25 kg seed ha^{-1} on well moistened soils and in WSR and TPR @ 50 kg seed ha^{-1}after ploughing, fields were flooded and puddled with tractor mounted cage wheels and levelled with rotovator. Prior to sowing, the seeds were soaked for 12 hours in water. After draining out the water, seeds were incubated for sprouting. In WSR well sprouted seeds were sown on following day through four-row drum seeder with a row to row spacing of 30 cm and in TPR sprouted seeds were broadcasted uniformly in nursery beds. In TPR 25 days old rice seedlings were transplanted, with 2 seedlings per hill^{-1} with spacing of 15 cm x 15 cm. The nutrient management was done as per recommendation made in package of practices for nursery bed preparation was 10-5-5 kg of $N:P_2O_5:K_2O$ per 1000 m^{-2} and for all the three rice establishment methods RDF i.e., 120-60-40 N, P_2O_5 and K_2O kg ha^{-1}, respectively. The entire P fertilizer was applied as basal in the form of DAP (46% P_2O_5 + 18 % N). The K fertilizer was applied in the form of muriate of potash (60 % K_2O) in two equal splits as basal and at panicle initiation stage.The fertilizer N was applied in the form of urea (46 % N) in three equal splits at basal, active tillering stage and at panicle initiation stage in DDSR and for WDSR and TPR fertilizer N was applied in three equal splits at 15-20 DAS, active tillering stage and at panicle initiation stage.

Nutrient studies focused on the nitrogen (N),phosphorus (P) and potassium (K) content in thegrains and straw. Samples of both grain andstraw were dried, ground and digested withspecific acid mixtures to estimate the nutrient content using standard procedures as mentioned in table 1. Additionally, the uptake of N, P andK by the grain and straw were calculated by using following formula.

$$\textbf{NPK uptake in grain/straw (kg ha}^{-1}\textbf{)} = \frac{\textbf{Nutrient content in grain/straw (\%) x dry matter (kg ha}^{-1}\textbf{)}}{\textbf{100}}$$

Table.1 Methods employed for plant analysis

S. No.	Nutrient	Method	Authority
1.	Total Nitrogen (%)	Kelplus- analyser distillation method Digestion: H_2SO_4 and K_2SO_4 + $CuSO_4$ 1:4 ratio in Kelplus block digestor	Subbiah and Asija (1956)
2.	Total Phosphorus (%)	Triple acid digestion and Vanadomolybdo phosphoric yellow color method with Barton’s reagent.The intensity of yellow color was determined by using UV-VIS Spectro photometer at 420 nm	Jackson (1973)
3.	Total Potassium (%)	Triple acid digestion and Flame photometry	Jackson (1973)

Statistical analysis

The data on phenology, nutrient content and uptake studied during the investigation were statistically analysed as suggested by Gomez and Gomez (1984). Wherever statistical significance was observed, critical difference (CD) at 0.05 level of probability was worked out for comparison. Non-significant comparison was indicated as 'NS'.

Results and discussion

Phenology of rice

Phenological parameters of days to 50 % flowering and maturity showed significant difference among different establishment methods as shown in table 2 during both the year of study i.e.,*kharif* 2021 and 2022. To attain 50 % flowering DDSR took 82.6, 82.5 and 82.6 days during *kharif* 2021, 2022 and on average basis, respectively and to attain maturity it took only 116.2, 115.7 and 116.0 days during both the years and on mean basis, respectively which was on par with WDSR for 50 % flowering viz., 85.6, 85 and 85.3, respectively and for maturity it took 119.6, 119.7 and 119.6 during *kharif* 2021, 2022 and on average basis, respectively.TPR took higher number of days to attain 50 % flowering viz., 88.7, 88.6 and 88.6 days and for maturity is 123.3, 122.8 and 123.0 days during *kharif* 2021, 2022 and on average basis, respectively. This difference could have been due to environmental shock imposed from uprooting of the seedlings until crop establishment for the transplanted rice. Overall, DDSR and TPR differed by about a week and DDSR & WDSR differed by 3 daysand between WDSR & TPR it was 3 days difference. Similar findings were reported by Dendup andChhogyel, 2018 and Thapliyal*et al*. 2020.

However, a non-significant difference was observed among irrigation scheduling treatments and interaction effect between stand establishment and irrigation scheduling (Table.2).

Nutrient studies

Data presented in table 3indicated that total NPK content recorded non-significant effect among different rice establishment methods and irrigation scheduling for both years of study. The percentage oftotal NPK content ranged from 0.89-1.03, 0.39-0.43 and 1.04-1.09,respectively for both the years of study.In both the years, non-significant increase was found in WDSR followed by TPR and DDSR. Negligible change was recorded in total NPK contentas influenced by rice establishment methods and irrigation scheduling treatments.

Contrastingly, total NPK uptake was found significant among establishment methods for both the years of study(Table 4). Among different establishment methods, WDSR (M_2) recorded significantly highertotal N uptake (125.8, 145.3 and 135.6 kg ha^{-1}), total P uptake (56.6, 60.8 and 58.7 kg ha^{-1}) and total K uptake (146.3, 153.4 and 149.9 kg ha^{-1}) during *kharif* 2021, 2022 and on mean basis, respectively followed by TPR (M_3) withtotal N uptake (117.7, 137.6 and 127.6 kg ha^{-1}), total P uptake (51.8, 56.0 and 53.9 kg ha^{-1}) and total K uptake (137.3, 145.4 and 141.3 kg ha^{-1}) and DDSR (M_1) withtotal N uptake (115.1, 132.7 and 123.9 kg ha^{-1}), total P uptake (50.2, 53.1 and 51.6 kg ha^{-1}) and total K uptake (134.6, 139.7 and 137.1 kg ha^{-1}) during *kharif* 2021, 2022 and on mean basis, respectively.However, the uptake ofthese nutrients was higher in WDSR due to its higher yield along with growth parameters and yield attributing characters (Lathwal*et al*. 2024).

In case of irrigation scheduling non-significant effect has been seen with total NPK uptake of rice during both the years viz., *kharif* 2021, 2022 and on mean basis (Table 4). However, continuous submergence (I_1) registered highertotal N uptake (122.6, 142.1 and 132.3 kg ha^{-1}), total P uptake (54.0, 58.2 and 56.1 kg ha^{-1}) and total K uptake (141.7, 147.9 and 144.8 kg ha^{-1}) during *kharif* 2021, 2022 and on mean basis, respectively followed by maintaining saturation (I_2) i.e., irrigation after disappearance of ponded waterwithtotal N uptake (118.1, 136.4 and 127.3 kg ha^{-1}), total P uptake (52.6, 56.5 and 54.6 kg ha^{-1}) and total K uptake (139.2, 145.5, and 142.4 kg ha^{-1}) and AWDI of 5 cm when water level in pipe falls 5 cm below surface (I_3) withtotal N uptake (117.8, 137.3 and 127.5 kg ha^{-1}), total P uptake (52.0, 55.2 and 53.6 kg ha^{-1}) and total K uptake (137.3, 145.1 and 141.2 kg ha^{-1}) during *kharif* 2021, 2022 and on mean basis, respectively.

Nutrient uptake is a function of dry matterproduction and is partly due to increase innutrient concentration. However, there is a closerelationship between the total uptake of nutrientswith the grain yield and straw yield of rice crop (Azam *et al.* 2024).Similar results were obtained by Keshry, 2023 thatthe N content of grain has two times higher than straw,phosphorus content in the grain was observed to be more thantwo-fold to that of straw and straw recorded four to five timeshigher potassium content than the grain under different riceestablishment methods. These findings are in line with Pramanik and Mondal, 2020.

Conclusion

From the study it can be concluded that among different rice establishment methods DDSR took less number of days to attain 50 % flowering and maturity than WDSR and TPR for both the years of study. Establishment methods and irrigation scheduling treatments has shown non-significant difference for nutrient content.However, there was a significant difference among establishment methods for nutrient uptake and non-significant effect for irrigation scheduling treatments. Interaction effect in both the cases like phenological parameters and nutrient studies was found to be non-significant.

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Table2.Phenology of rice as influenced by different planting methods and irrigation scheduling during *kharif* 2021 & 2022

Treatments	Days to 50 % flowering			Days to maturity		
Main plots	**2021**	**2022**	**Mean**	**2021**	**2022**	**Mean**
M$_1$: Dry direct seeding of rice with seed drill (DDSR)	82.6	82.5	82.6	116.2	115.7	116.0
M$_2$: Wet direct seeding of rice with drum-seeder (WDSR)	85.6	85.0	85.3	119.6	119.7	119.6
M$_3$: Manual transplanted puddled rice (TPR)	88.7	88.6	88.6	123.3	122.8	123.0
SEm±	1.0	1.1	1.0	1.0	0.9	0.9
CD (P=0.05)	3.7	4.3	4.0	3.9	3.6	3.7
Sub plots						
I$_1$: Continuous submergence (CS)	85.1	84.7	84.9	119.2	118.7	118.9
I$_2$: Maintaining saturation (after disappearance of ponded water)	85.6	85.4	85.5	119.8	119.4	119.6
I$_3$: Alternate wetting and drying irrigation(AWDI)	86.2	86.0	86.1	120.2	120.1	120.2
SEm±	1.2	1.2	1.2	1.2	1.2	1.2
CD (P=0.05)	NS	NS	NS	NS	NS	NS
Interaction						
SEm±	1.9	2.0	2.0	2.0	2.0	2.0
CD (P=0.05)	NS	NS	NS	NS	NS	NS
Interaction						
SEm±	2.1	2.0	2.1	2.1	2.1	2.1
CD (P=0.05)	NS	NS	NS	NS	NS	NS

Table3.Total NPK content (%)at harvest of rice as influenced by different planting methods and irrigation scheduling during *kharif* 2021 & 2022

Treatments	Total NPK content (%) at harvest								
	Total N (%)			Total P (%)			Total K (%)		
Main plots	**2021**	**2022**	**Mean**	**2021**	**2022**	**Mean**	**2021**	**2022**	**Mean**
M_1: DDSR	0.89	0.99	0.94	0.39	0.40	0.39	1.04	1.04	1.04
M_2: WDSR	0.93	1.03	0.98	0.42	0.43	0.43	1.08	1.09	1.09
M_3: TPR	0.90	1.00	0.95	0.40	0.41	0.40	1.05	1.06	1.06
SEm±	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sub plots									
I_1: CS	0.92	1.02	0.97	0.41	0.42	0.41	1.07	1.06	1.06
I_2: Saturation	0.90	1.00	0.95	0.40	0.41	0.41	1.06	1.07	1.06
I_3: AWDI	0.90	1.00	0.95	0.40	0.40	0.40	1.05	1.06	1.06
SEm±	0.02	0.02	0.02	0.01	0.01	0.01	0.02	0.01	0.01
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction									
SEm±	0.03	0.03	0.03	0.01	0.02	0.01	0.03	0.02	0.02
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction									
SEm±	0.03	0.03	0.03	0.01	0.02	0.01	0.03	0.03	0.02
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

DDSR: Dry direct seeding of rice with seed drill
WDSR: Wet direct seeding of rice with drum-seeder
TPR: Manual transplanted puddled rice
CS: Continuous submergence
AWDI: Alternate wetting and drying irrigation

Table4.Total NPK uptake (kg ha^{-1}) at harvest of rice as influenced by different planting methods and irrigation scheduling during *kharif* 2021 & 2022

Treatments	Total NPK uptake (kg ha^{-1}) at harvest								
	Total N uptake (kg ha^{-1})			Total P uptake (kg ha^{-1})			Total K uptake (kg ha^{-1})		
Main plots	**2021**	**2022**	**Mean**	**2021**	**2022**	**Mean**	**2021**	**2022**	**Mean**
M_1: DDSR	115.1	132.7	123.9	50.2	53.1	51.6	134.6	139.7	137.1
M_2: WDSR	125.8	145.3	135.6	56.6	60.8	58.7	146.3	153.4	149.9
M_3: TPR	117.7	137.6	127.6	51.8	56.0	53.9	137.3	145.4	141.3
SEm±	1.5	1.6	1.5	0.9	1.3	1.1	2.0	1.8	1.6
CD (P=0.05)	5.8	6.4	6.0	3.7	5.0	4.3	7.8	7.0	6.5
Sub plots									
I_1: CS	122.6	142.1	132.3	54.0	58.2	56.1	141.7	147.9	144.8
I_2: Saturation	118.1	136.4	127.3	52.6	56.5	54.6	139.2	145.5	142.4
I_3: AWDI	117.8	137.3	127.5	52.0	55.2	53.6	137.3	145.1	141.2
SEm±	3.0	2.2	2.5	0.9	1.2	0.8	1.8	2.2	1.9
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction									
SEm±	4.5	3.5	3.9	1.6	2.1	1.6	3.3	3.6	3.2
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction									
SEm±	5.2	3.7	4.4	1.6	2.1	1.4	3.2	3.8	3.3
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

DDSR: Dry direct seeding of rice with seed drill
WDSR: Wet direct seeding of rice with drum-seeder
TPR: Manual transplanted puddled rice
CS: Continuous submergence
AWDI: Alternate wetting and drying irrigation