Indian Journal of Agricultural Sciences **94** (5): 467–471, May 2024/Article
https://doi.org/10.56093/ijas.v94i5.142069

Performance of basmati rice (*Oryza sativa*) under variable irrigation and nitrogen management

KAVITA KUMARI[1,2], ANCHAL DASS[1]*, SHIVA DHAR[1], S SUDHISHRI[1], RAJIV KUMAR SINGH[1], T K DAS[1] and ALKA RANI[3]

ICAR-Indian Agricultural Research Institute, New Delhi 110 012, India

Received: 06 September 2023; Accepted: 09 January 2024

ABSTRACT

A field experiment was conducted during the rainy seasons (*kharif*) of 2021 and 2022 at research farm of ICAR-Indian Agricultural Research Institute, New Delhi to study the effect of irrigation regimes and integrated use of prilled urea and nano-urea as a source of N, on productivity and profitability of basmati rice (*Oryza sativa* L.). The experiment was conducted in a three-time replicated split-plot design (SPD) comprised of 3 irrigation regimes, viz. irrigation at 1, 3 and 6 days after disappearance of surface water (DADSW) assigned to main-plots and 4 N-management variants including; 100% RDN (recommended dose of N, 120 kg/ha); 75% RDN + 4% nano-urea (NU) 2 sprays (75% RDN + 2 NU); 50% RDN + 2 NU; and no-N (control) in sub-plots. Irrigating basmati rice 1 DADSW exhibited the highest panicle weight (2.67–3.09 g) and number of grains/panicle (115.9, 109.8), across the years, respectively that were significantly higher than 3 and 6 DADSW. The most delayed irrigation at 6 DADSW caused significant reduction in grain yield, the magnitude of reduction was 13–19% over irrigation at 3 DADSW and substantially by 23–28% over 1 DADSW. Fertilizing rice crop with 100% RDN and 75% RDN + 2 NU resulted in statistically similar yield attributes and grain yield; however, both were, significantly superior to 50% RDN + 2 NU and no-N. Net returns, benefit cost (B:C) ratio and monetary efficiency were significantly higher when crop was irrigated 1 DADSW than 3 and 6 DADSW. The N-management options followed the trend as RDN>75% RDN + 2 NU >50% RDN > no-N for all studied economic parameters.

Keywords: Basmati rice, Economics, Irrigation, Nano-urea, Nitrogen, Yield

Rice (*Oryza sativa* L.), vital for half of the global population's nutrition, is pivotal in combating food insecurity, especially in economically vulnerable nations (Dass *et al.* 2016, Wasaya *et al.* 2022). India, contributing 21% to global rice output, faces the challenge of meeting a projected demand of 130 million tonnes by 2025 for national food security and UN sustainable development goals (Choudhary *et al.* 2022). Despite being the leading rice exporter, India's increasing population and dietary shifts impose a focus on boosting production (Mohidem *et al.* 2022). However, achieving higher yields is challenging under diminishing resources, notably water scarcity.

Rice cultivation, consuming 34–43% of global irrigation water (Surendran *et al.* 2021), possess a significant challenge in water-scarce nations like India and China. India faces a predicted 50% supply-demand gap by 2030 due to declining water availability (Gulati *et al.* 2019). Conventional transplantation consumes substantial water, whereas, studies showed no significant impact on basmati rice yield with a 2–3 day irrigation interval (Mahajan *et al.* 2006, Singh *et al.* 2008).

Nitrogen (N), a crucial nutrient, impacts crop yields (Zhang *et al.* 2020), and nano-fertilizers, like those enhancing nutrient transport through nano-sized channels (Mahanta *et al.* 2019), show promise in improving plant biomass and yield (Khalid *et al.* 2022). Nano-urea, when combined with urea (traditional N-source) enhances agricultural outcomes by promoting meristematic activity, cell elongation, photosynthate assimilation, and efficient resource translocation within plants, resulting in improved yield attributes and economics (Sahu *et al.* 2022, Kannoj *et al.* 2022, Attri *et al.* 2022, Ranjan *et al.* 2023). Keeping this in view the field experiments were conducted with the main objective to study the effect of irrigation regimes and integrated use of prilled urea and nano-urea as source of N, on productivity and profitability of *basmati* rice.

MATERIALS AND METHODS

A field experiment was conducted during the rainy (*kharif*) seasons of 2021 and 2022 at research farm of ICAR-Indian Agricultural Research Institute (28°38′ N;

[1]ICAR-Indian Agricultural Research Institute, New Delhi; [2]ICAR-National Rice Research Institute, Cuttack, Odisha; [3]ICAR-Indian Institute of Soil Science, Bhopal, Madhya Pradesh. *Corresponding author email: anchal_d@rediffmail.com

77°09′ E; 229 m msl), New Delhi. The monthly mean maximum and minimum air temperatures were 33.8 and 24.5°C and 33.6 and 23.9°C during *kharif 2021* and 2022, respectively. The experimental field soil was Alluvial with sandy loam texture, and the initial soil chemical characteristics (0–15 cm depth) were recorded as Walkley-Black soil organic carbon (SOC) 0.5%, and alkaline $KMnO_4$ oxidizable–N, 0.5 M $NaHCO_3$ extractable phosphorus (P), and 1 N NH_4OAc extractable potassium (K) contents as 254.2 kg/ha, 14.4 kg/ha, and 222.6 kg/ha, respectively, using standard protocols (Rana *et al.* 2014). The experiment consisted of 3 main-plot treatments, viz. irrigations, applied 1, 3 and 6 days after disappearance of surface water (1, 3, 6 DADSW); and 4 sub-plot N-management treatments, viz. 100% recommended dose of N i.e. 120 kg/ha in split doses (RDN); 75% RDN + nano urea (NU) with 2 sprays (75% RDN + NU); 50% RDN + nano urea spray (50% RDN + NU); and control plot where N was omitted (N_0). The experiment was laid out in a split-plot design (SPD) in 36 plots with 3 replications. The recently developed high yielding, early maturing, non-lodging, and non-shattering, moderately resistance to blast disease, semi-dwarf Pusa Basmati 1692 having extra-long and slender grains was taken as test variety (basmati rice). The plots were prepared by ploughing, followed by harrowing to obtain a fine seed bed and nursery-raised with pre-germinated seeds on well-irrigated and well-fertilized beds in June last week and transplanted in the main field with a spacing of 20 cm ×10 cm and 2 seedlings/hill during mid–July. Crop was irrigated (6 cm depth) at 1, 3, and 6 days after disappearance of surface water from tillering to milking stages; thereafter, irrigations were given uniformly. Total number of irrigations varied according to treatment (1 DADSW-11, 15; 3 DADSW: 7, 11; 6 DADSW: 5, 7 during 2021 and 2022 respectively), where number of irrigations got affected by the rainfall amount received in each year. Crop was fertilized as per treatments, 3 split doses of 120 kg/ha N were applied as RDN in the form of urea, then 75% of RDN (90 kg/ha N) and 50% of RDN (60 kg/ha N) were applied along with two nano-urea sprays. The basal dose was applied as one-third of RDN (40 kg/ha), 60 kg/ha P_2O_5, and 40 kg/ha K_2O in the form of urea, single superphosphate (SSP), and muriate of potash (MOP), while the rest of the N and 4% nano-urea spray were applied at about 25–30 and 45–50 DAT (days after transplanting) at the rate of 500 ml/acre. For weed management, pre-emergence application of butachlor 1.5 kg a.i./ha in combination with 2-hand weedings at 30 and 60 DAT were done. For yield attributes, number of panicles/m^2 were counted randomly from 3 sites in each plot at harvest by using 1 m^2 quadrate. Number of individuals filled grains/hill were averaged from randomly selected 10 panicles taken from each plot and counted. Test weight (g) was evaluated by randomly taking 1000-grains from the bulk produce of each net-plot and counted, and weighed at 14% moisture content. The rice crop was harvested from net-plot sun dried, threshed, winnowed and cleaned separately plot-wise manually and reported as grain yield (t/ha) at 14% moisture content. The cost of cultivation (COC) was computed by combining the expenses of all the inputs and resources, viz. land preparation, seed cost, transplanting cost, fertilizers, labour, machinery, irrigation, etc. For calculating the gross returns, the economic produce (grain plus straw) was multiplied by the prevailing market price (₹3700/q in 2021 and ₹4000/q in 2022, and straw price, ₹2/kg) of rice and further subtracted from the COC to arrive the net returns. The net benefit-cost (B:C) ratio was determined by dividing the net returns by the cost of cultivation. Monetary efficiency (ME) was computed by dividing net returns by crop duration. Year-wise data on all observations were subjected to the Analysis of Variance technique for a split-plot design using the standard procedure. The significant difference among different treatments was tested with F-test, and the least significant difference (LSD) values were computed for the parameters that exhibited significant differences. The treatment means were compared at a 5% level of significance.

RESULTS AND DISCUSSION

The yield attributing characters were considerably affected by irrigation regimes and N-management (Table 1). The panicle length was notably higher with irrigating rice at 1 DADSW, closely followed without any significant variations with 3 DADSW. The panicle length was significantly reduced (12–15%) with delayed interval at 6 DADSW. Among N-management options, highest panicle length was recorded in the RDN, succeeded by 75% RDN + NU, without any significant differences. The irrigation at 1 DADSW also exhibited the highest panicle weight (2.67 to 3.09 g) across the years and was significantly different from irrigation regimes at 3 and 6 DADSW. Though panicle weight didn't get influenced significantly by shifting irrigation from 3 DADSW to 6 DADSW. Considering the N-management in 2021, RDN yielded the highest panicle weight (3.0, 2.67 g), but was statistically at par with 75% RDN + NU and exhibited significantly higher over other treatments. Irrigation at 1 DADSW led to significantly higher number of grains/panicle (115.9 and 109.8), over delayed irrigation that further reduced it by 3–9% (3 DADSW) and 11–15% (6 DADSW) across the years respectively. Among N treatments, RDN produced maximum number of grains/panicle (115.1 and 113.03) and it was statistically at par with 75% RDN + NU. RDN produced about 10–11% higher no. of grains/panicle over 50% RDN + NU and 21–24% over control across the years.

When crop was irrigated at 1 DADSW and fertilized with 75% of the recommended nitrogen dose along with twice nano-urea spray led to better grain filling over other treatments. Among all regimes, irrigation scheduling at 1 DADSW led to higher test weight (27.7, 27.67 g), though during second year the difference was at par with 3 DADSW. However, further withholding the irrigation up to 6 DADSW led to considerable reduction in test weight (24.97, 24.32 g), which was about 9–12% across the years, more reduction was seen during second year.

Table 1 Effect of irrigation regimes and nitrogen management on yield attributes and yield of basmati rice

Treatment	Panicle length (cm)		Panicle weight (g)		Grains/ panicle		Un-filled grains/ panicle		1000-grain wt. (g)		Grain yield (t/ha)	
	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022
Irrigation regimes												
1 DADSW	27.17	27.14	3.09	2.67	115.9	109.75	6.50	7.59	27.70	27.67	5.01	4.92
3 DADSW	26.20	25.37	2.54	2.23	105.4	106.22	9.56	12.22	26.77	26.05	4.43	4.35
6 DADSW	23.82	23.20	2.31	1.98	98.3	97.66	13.00	17.35	24.97	24.32	3.84	3.54
SEm ±	0.49	0.51	0.05	0.04	2.38	2.22	0.19	0.19	0.44	0.54	0.10	0.09
CD (P=0.05)	1.93	2.00	0.19	0.15	9.33	8.71	0.74	0.76	1.74	2.11	0.38	0.34
N-management												
RDN	28.12	27.44	3.00	2.69	115.1	113.03	7.73	10.01	27.36	27.02	5.19	5.05
75% RDN + NU	27.14	26.75	2.94	2.64	113.2	112.21	6.89	8.96	27.84	27.58	4.99	4.81
50% RDN + NU	25.27	24.52	2.58	2.15	104.3	101.83	9.92	12.23	26.20	25.76	4.48	4.31
N_0	22.39	22.24	2.08	1.69	93.4	91.10	14.20	18.33	24.52	23.69	3.05	2.92
SEm ±	0.39	0.37	0.06	0.03	2.34	2.82	0.23	0.31	0.33	0.57	0.07	0.08
CD (P=0.05)	1.16	1.09	0.17	0.10	6.98	8.41	0.69	0.94	0.99	1.69	0.22	0.25
Interaction (I × N)	S	NS	S	S	NS	NS	S	S	S	NS	S	S

DADSW, Days after disappearance of surface water; RDN, Recommended dose Nitrogen; NU, Nano-urea.

Among N treatments, application of 75% RDN + NU and RDN was at par and resulted in producing significantly higher test weight over rest of the N treatments. Application of 75% RDN + NU led to highest 1000-grain weight (27.84, 27.58 g) and it was 6–7% higher over 50% RDN + NU and about 13–16% over control treatment across the years. Significant differences in grain yield were observed across all the irrigation regimes studied during year 2021 and 2022 (Table 1). Providing irrigation at 1 DADSW and fertilization with RDN produced maximum grain yield. Though substituting 25% N with 2 spray of 4% nano-urea didn't cause significant reduction in grain yield. Whereas, on the other hand, the most delayed irrigation at 6 DADSW resulted in lowest grain yield (3.84, 3.54 t/ha), and the magnitude of this reduction was 13–19% over irrigation at 3 DADSW and substantially by 23–28% over 1 DADSW across the years. Significantly higher grain yield (5.01, 4.92 t/ha) due to frequent irrigation, might be owing to improved soil-water ecosystem, coping evapotranspiration (ET) losses by reducing water stress, better soil and applied nutrient solubilization, absorption and assimilation resulted in the better crop growth by translocating more photosynthates to the sink, thus better grain filling, ultimately to improved yield attributes and yield (Parihar 2004, Kumari *et al.* 2017, Pratap *et al.* 2022). Delayed irrigation imposed stress likely led to stunted plant growth, reduced leaf area, fewer tillers, decreased dry matter production, reduced panicle number and length, lower 1000-grain weight, inadequate grain filling, and smaller and lighter grains, ultimately resulting in lower straw and grain yields (Rahman *et al.* 2002). Among the N treatments, application of RDN recorded the highest grain yield (5.19, 5.05 t/ha), which was statistically par with 75% RDN + NU (4.99, 4.81 t/ha), and significantly superior over other treatments during both the years. Over the course of study years, RDN produced 14–15% and 41–42% higher yield as compared to 50% RDN + NU and control (N_0) respectively. This might be attributed to the fact that, N application in sufficient quantity contributes to cell division and elongation, stimulates tiller production, increased leaf area index, improves panicle growth leading to synthesis of and transfer of carbohydrates to the grains leading to better yield attributes and yield. The increase in yield attributes and grain yield have also been reported with N 120 kg/ha (Jaiswal and Singh 2001). Supplementing 25% N through nano-urea might have also compensated the yield loss is due to its higher uptake, this might be because of its nano-scale particle size, provides a higher surface area, quick absorption, penetration, and slow release of nano-nutrients allowing plants to completely utilize it, and resulting in a rise in plant biomass and hence more yield (Khalid *et al.* 2022). Chandana *et al.* (2021) and Sahu *et al.* (2022) also reported that, nitrogen combined with nano-urea led to better yield attributes like highest no. of panicle/m^2 and number of filled grain/panicle concurrently led to better grain yield.

The economic returns on agricultural output, which takes into account a number of variables including crop yield, quality, market pricing, input costs, and water availability was greatly influenced by irrigation and nitrogen management. The economic analysis of the applied irrigation and nitrogen (Table 2) revealed that frequent irrigation treatment resulted in the highest gross returns, net returns (143,699 ₹/ha, 150,019 ₹/ha), net B:C ratio (2.47, 2.41) and monetary efficiency (1218, 1271 ₹/ha/day) during 2021 and 2022 respectively. Overall, across the years, comparing

Table 2 Effect of irrigation regimes and nitrogen management on economic return in basmati rice

Treatment	Gross return (₹/ha)		Net return (₹/ha)		Net B:C ratio		Monetary efficiency (₹/ha/day)	
	2021	2022	2021	2022	2021	2022	2021	2022
Irrigation regimes								
1 DADSW	201687	212007	143699	150019	2.47	2.41	1218	1271
3 DADSW	177579	186480	123591	128492	2.28	2.21	1056	1120
6 DADSW	152796	151111	100808	97123	1.93	1.79	908	883
SEm ±	3979	4318	2490	3623	0.06	0.06	23.3	25.6
CD (*P*=0.05)	15620	16950	9775	14222	0.24	0.25	91.6	100.6
N management								
RDN	208796	216927	153807	158605	2.78	2.70	1325	1369
75% RDN + NU	199989	206130	144618	147426	2.60	2.49	1246	1273
50% RDN + NU	178456	184623	123265	126099	2.22	2.14	1063	1115
N_0	122176	125118	69108	68716	1.30	1.21	609	609
SEm ±	2710	3328	2241	3207	0.04	0.05	18	26.4
CD (*P*=0.05)	8085	9929	6687	9568	0.13	0.14	53.7	78.7
Interaction (I × N)	S	S	S	S	S	S	S	S

DADSW, Days after disappearance of surface water; RDN, Recommended dose of Nitrogen; NU, Nano-urea; B:C, Benefit cost.

RDN, reducing N-dose by 75% RDN + NU; and 50% RDN + NU reduced net return by 6–7% and 19–20% respectively. In this context, Attri *et al*. (2022) reported that 75% RDN along with Nano-urea was most economical. On the other hand, 100% RDN along with nano spray has also been seen to give best economic return and B:C ratio (Ranjan *et al.* 2023). Monetary efficiency was mainly governed by the net returns and crop duration (Dass *et al.* 2022, Pratap *et al.* 2022); frequent irrigation and RDN led to better monitory efficiency. Taking into account the advantages of using 75% RDN + nano-urea compared to RDN, specifically in terms of saving energy and reducing greenhouse gas emissions, may encourages its adoption for the sake of environmental sustainability (Upadhyay *et al.* 2023).

Based on the 2-year experiment it can be concluded that irrigating rice at 1 DADSW and fertilization with RDN led to higher yield attributes, yield and economic return. There were no significant differences between RDN and 75% RDN + 2 nano-urea sprays for yield attributes and yield, however, the use of nano-urea needs to be further optimized for improved productivity and quality of basmati rice.

REFERENCES

Attri M, Sharma N and Sharma B C. 2022. Effect of foliar application of nano-urea on productivity and profitability of fine rice under irrigated subtropics of Jammu region. *Indian Journal of Ecology* **49**(5): 1935–938.

Chandana P, Latha K R, Chinnamuthu C R, Malarvizhi P and Lakshmanan A. 2021. Impact of foliar application of nano nitrogen, zinc and copper on yield and nutrient uptake of rice. *International Journal of Plant and Soil Science* **33**(24): 276–82.

Choudhary A K, Sood P, Rahi S, Yadav D S, Thakur O C, Siranta K R, Dass A, Singh Y V, Kumar A, Vijayakumar S and Bhupenchandra I. 2022. Rice productivity, Zn bio-fortification, and nutrient-use efficiency as influenced by Zn fertilization under conventional transplanted rice and the system of rice intensification. *Frontiers in Environmental Science* **10**: 869194.

Dass A, Chandra S, Choudhary A K, Singh G and Sudhishri S. 2016. Influence of field re-ponding pattern and plant spacing on rice root-shoot characteristics, yield, and water productivity of two modern cultivars under SRI management in Indian Mollisols. *Paddy and Water Environment* **14**: 45–59.

Dass A, Rajanna G A, Babu S, Lal S K, Choudhary A K, Singh R, Rathore S S, Kaur R, Dhar S, Singh T and Raj R. 2022. Foliar application of macro-and micronutrients improves the productivity, economic returns, and resource-use efficiency of soybean in a semiarid climate. *Sustainability* **14**(10): 5825.

Gulati A, Sharma B, Banerjee P and Mohan G. 2019. Getting More from Less: Story of India's Shrinking Water Resources, pp. 170. NABARD and ICRIER Report, Indian Council for Research on International Economic Relations, New Delhi, India.

Jaiswal V P and Singh G R. 2001. Effect of planting methods, source and level of nitrogen on the growth and yield of rice (*Oryza sativa*) and on succeeding wheat (*Triticum aestivum*). *Indian Journal of Agronomy* **46**(1): 5–11.

Kannoj J, Jain D, Tomar M, Patidar R and Choudhary R. 2022. Effect of nano-urea vs conventional urea on the nutrient content, uptake and economics of black wheat (*Triticum aestivum* L.) along with Biofertilizers. *Biological Forum* **14**(2): 499–504.

Khalid U, Sher F, Noreen S, Lima E C, Rasheed T, Sehar S and Amami R. 2022. Comparative effects of conventional and nano-enabled fertilizers on morphological and physiological attributes of *Caesalpinia bonducella* plants. *Journal of the Saudi Society of Agricultural Sciences* **21**(1): 61–72.

Kumari K, Dass A, Sudhishri S, Kaur R and Rani A. 2017. Yield components, yield and nutrient uptake pattern in maize (*Zea mays*) under varying irrigation and nitrogen levels. *Indian Journal of Agronomy* **62(**1): 104–07.

Mahajan G, Sardana V, Brar A S and Gill M S. 2006. Effect of seed rates, irrigation intervals and weed pressure on productivity of direct-seeded rice (*Oryza sativa*). *Indian Journal of Agricultural Sciences* **76**(12): 756–59.

Mahanta N, Dambale A, Rajkhowa M, Mahanta C and Mahanta N. 2019. Nutrient use efficiency through nano-fertilizers. *International Journal of Chemical Studies* **7**(3): 2839–842.

Mohidem N A, Hashim N, Shamsudin R and Che Man H. 2022. Rice for food security: Revisiting its production, diversity, rice milling process and nutrient content. *Agriculture* **12**: 741.

Parihar S S. 2004. Effect of crop-establishment method, tillage, irrigation and nitrogen on production potential of rice (*Oryza sativa*)-wheat (*Triticum aestivum)* cropping system. *Indian Journal of Agronomy* **49**(1): 1–5.

Pratap V, Dass A, Dhar S, Babu S, Singh V K, Singh R, Krishnan P, Sudhishri S, Bhatia A, Kumar S, Choudhary Anil K, Singh, R, Kumar P, Sarkar S K, Verma S K, Kumari K and San A A. 2022. Co-implementation of tillage, precision nitrogen, and water management enhances water productivity, economic returns, and energy-use efficiency of direct-seeded rice. *Sustainability* **14**(18): 11234.

Rahman M T, Islam M T and Islam M O. 2002. Effect of water stress at different growth stages on yield and yield contributing characters of transplanted *aman* rice. *Pakistan Journal of Biological Sciences* **5**: 169–72.

Rana K S, Choudhary A K, Sepat S, Bana R S and Dass A. 2014. *Methodological and Analytical Agronomy,* pp. 276. Post Graduate School, Indian Agricultural Research Institute, New Delhi, India.

Ranjan P, Kumar B, Mala A, Priyadarshi S, Shri A, Babu L, Narayan A and Kumar B. 2023. Effect of foliar spray of nano urea on yield and economics of rice. *The Pharma Innovation Journal* **12**(1): 3030–33.

Sahu T K, Kumar M, Kumar N, Chandrakar T and Singh D P. 2022. Effect of nano-urea application on growth and productivity of rice (*Oryza sativa* L.) under mid land situation of Bastar region. *Pharma Innov*ation **11**: 185–87.

Singh R D, Sikka A K, Shivani and Rajan K. 2008. Effect of irrigation and nitrogen on yield, water-use efficiency and nutrient balance in rice (*Oryza sativa*) based cropping system. *The Indian Journal of Agricultural Sciences* **78**: 21–26.

Surendran U, Raja P, Jayakumar M and Subramoniam S R. 2021. Use of efficient water saving techniques for production of rice in India under climate change scenario: A critical review. *Journal of Cleaner Production* **309**: 127272.

Upadhyay P K, Dey A, Singh V K, Dwivedi B S, Singh T, GA R, Babu S, Rathore S S, Singh R K, Shekhawat K and Rangot M. 2023. Conjoint application of nano-urea with conventional fertilizers: An energy efficient and environmentally robust approach for sustainable crop production. *Plos One* **18** (7): 0284009.

Wasaya A, Yasir T A, Sarwar N, Mubeen K, Rajendran K, Hadifa A and Sabagh A E. 2022. Climate change and global rice security. *Modern Techniques of Rice Crop Production*, pp. 13–26. Springer, Berlin/Heidelberg, Germany.

Zhang J, Tong T, Potcho P M, Huang S, Ma L and Tang X. 2020. Nitrogen effects on yield, quality and physiological characteristics of giant rice. *Agronomy* **10**(11): 1816.