



## Effect of nano-urea and irrigation regimes on growth parameters of wheat (*Triticum aestivum* L.)

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### ABSTRACT

Wheat (*Triticum aestivum* L.) is a crucial cereal crop globally, serving as a staple food for a vast population. Its productivity faces challenges such as nutrient imbalance and terminal heat stress exacerbated by climate change, particularly in regions like the North-Eastern Plain Zone of India. To address these issues, a study was conducted during the *rabi* season of 2021–2022 in Jharkhand, India, aiming to examine the impacts of irrigation regimes and nano-urea-based nitrogen management practices on wheat. Employing a split-plot design with three replications, the experiment assessed three irrigation regimes and five nitrogen management practices. Results revealed that irrigation regimes registered non-significant effects on crop growth parameters like plant height, LAI (leaf area index), root dry weight, flag leaf area and tillers/m<sup>2</sup>, which might be due to frequent rain up to the flowering stage during the crop growth period. Higher levels of nitrogen in commercial urea significantly increased plant height, LAI, flag leaf area, recovered root dry weight and dry matter accumulation. However, nano-urea spray at 45 DAS helped crop plants positively to increase all growth parameters more compared to nano-urea spray at 60 DAS. All growth attributes with 50% RDN+2-nano-urea spray were statistically at par with 50% RDN+1 nano-urea spray up to 40 DAS, but after the flowering stage, it was statistically similar with 100% RDN. The maximum tillers/m<sup>2</sup> was found under 100% RDN, followed by 75% RDN+ one nano-urea spray and 50% RDN+2 nano-urea spray. Thus, 3-irrigations at CRI, flowering and milk stage and 100% RDN (120 kg N/ha) were found sufficient for enhancing the growth parameters of wheat.

**Key words:** Irrigation regimes, Nano-urea, Growth parameters, Wheat

Wheat (*Triticum aestivum* L.) is the most extensively grown cereal crop in the world and is used as a staple food by nearly 2.5 billion people in the world. Apart from the imbalance use of nutrients, terminal heat stress due to changing climate regularly affects wheat growth parameters. Due to terminal heat stress, climate change, and other constraints, the area under wheat is gradually decreasing day by day. To meet this huge demand, we need to give great emphasis on boosting productivity from the present level of 3.3 t/ha to 4.7 t/ha. Wheat in the North-Eastern Plain Zone of India, i.e., Eastern Uttar Pradesh, Jharkhand, Bihar, West Bengal, Odisha, Assam, and other North-East-

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ern states, is part of one of the largest agricultural production systems, viz., rice-wheat rotation, occupying more than 11 M ha. The yield potential of wheat in this zone is about 4.5 t/ha, but farmers generally realize a yield of only 2.2 t/ha (Kumar *et al.*, 2018). Constraints like unfavourable climatic conditions, undulating topography, waterlogged soil, low seed replacement rate, poor nutrient and water management, lack of machinery, price volatility, unavailability of labour and good quality seed, and delay in sowing are the causes of low productivity of wheat in this region. To achieve an improvement in productivity, the wheat crop needs to increase its growth parameters through timely applications of water and nitrogen, that helps better carbohydrate synthesis, results better translocation into grains. Nowadays, irrigation at critical stages of wheat growth has received substantial attention. Specific reduction in irrigation water had no discernible impact on wheat productivity but considerably raised crop water productivity. As nitrogen is a significant constituent of chlorophyll, the photosynthesis in green leaves might be increased by nitrogen fertilization, which helps in better translocation

from leaves to grains. Nanotechnology emerged as an innovative solution for addressing the issue of low or declining NUE (nutrient use efficiency) with a minimal environmental footprint (Kumar *et al.*, 2021). The nanoparticles release nutrients in a controlled manner to plant parts where nitrogen is required, thereby reducing the usage (up to 50%), increasing efficiency, and reducing wastage in the environment. There has been a lot of interest in using NPs (Nanoparticles) on plants for agricultural management during the past few years. So, keeping these facts in view, it was essential to see the effect of irrigation regimes and nano-urea-based nitrogen management practices on various growth parameters of wheat.

The field experiments were performed during the rabi season of 2021–2022 at ICAR-Indian Agricultural Research Institute farm, Jharkhand, located at 24°16' N latitude, 85°21' E longitude and 628 m above mean sea level. This region represents the semi-arid and sub-tropical climate with hot, dry summer and moderately cold winter from the end of November to January, which comes under the taxonomic classification of hyperthermic mixed Typic Paleustaff. The soil of the experimental field was sandy clay loam in texture having good drainage and moderate water holding capacity. The soil was acidic in reaction (pH 5.85), low in EC (0.712 dS/m), low in cation exchange capacity {7.8 cmol (P<sup>+</sup>)/ kg}, low in organic carbon (0.25%), low in available nitrogen (150.6 kg N/ha), and available phosphorus (8.27 kg P/ ha) and medium in available potassium (132.16 kg K/ ha). The crop received total rainfall of 100.5 mm during the crop growth period. Still, it was not evenly distributed throughout the season. The experiment was laid out in split plot design with three replications. Main plots consist of 3-irrigation regimes viz., I<sub>1</sub> (5-irrigations; CRI, late jointing, flowering, milk and dough stage); I<sub>2</sub> (3-irrigations at CRI, flowering & milking stage) and I<sub>3</sub> (2-irrigations at CRI & flowering stage) while in sub-plots 5-nano-urea based N management techniques viz., N<sub>0</sub> (control, without N); N<sub>1</sub> (100% RDN-120 kg N/ha, 1/3<sup>rd</sup> basal+1/3<sup>rd</sup> at CRI and 1/3<sup>rd</sup> at 2<sup>nd</sup> irrigation); N<sub>2</sub> (50% RDN (1/2 basal + 1/2 at CRI) + nano-urea spray at 60 DAS); N<sub>3</sub> (50% RDN (1/2 basal + 1/2 at CRI) + 2 nano-urea spray at 45 & 70 DAS); and N<sub>4</sub> (75% RDN (1/2 basal + 1/2 at CRI) + nano-urea spray at 60 DAS. The fertilizer nitrogen (N) in prilled urea was applied as per the treatments and full P and K were applied as basal @ N: P<sub>2</sub>O<sub>5</sub>: K<sub>2</sub>O- 120:60:40 kg/ha. Nano-urea was applied @ 4ml/litre of water in the evening as per the treatment. The variety of wheat 'DBW-187' (Karan Vandana) was sown in lines with 22.5cm spacing using a seed rate of 100 kg/ha, on 2<sup>nd</sup> December, 2021. Plant protection measures were taken against insects, weeds and diseases. Periodically growth parameters viz., plant height, dry matter accumulation,

LAI, root dry weight, flag leaf area and tillers/m<sup>2</sup> were recorded from the plot. The harvested plant biomass and collected roots were dried in the sun and then dried in an oven at 60 °C until they reached a consistent weight. The results were expressed as g/m<sup>2</sup>. The collected leaf samples (from 25 cm row length) were taken to the lab immediately and the readings were taken with the help of a leaf area meter. LAI was calculated with following mathematical expression given by Watson, 1947.

$$\text{LAI} = \frac{\text{Total leaf area per plant (cm}^2\text{)}}{\text{Land area per plant (cm}^2\text{)}}$$

Data analysis was performed for split-plot design using an online data analysis module, i.e., strengthening statistical computing for the NARS portal. The treatments were compared at a significance level of 5%, the critical difference (CD) and standard error of means (SEM±) for each character were computed.

The data showed that plant height continued to increase with advancement in crop age, and this increase was rapid up to the flowering stage, and further up to the harvest, there was a negligible accretion in plant height (Table 1). There was no variation in the plant height among the irrigation treatments in crop growth. The main reason behind this was the occurrence of frequent rainfall during the vegetative growth stages of the crop. Among nitrogen management practices the minimum height was found in the control plot in all stages due to the unavailability of sufficient N in the soil (Kumar *et al.*, 2018). The maximum plant height was observed at 40, 80 DAS and harvest under N<sub>1</sub> treatment where 100% nitrogen was applied as prilled urea in 3 split doses. In N<sub>3</sub> treatment, we applied nano-urea at 45 & 70 DAS, which guided the plant to increase rapidly compared to other nano-urea treatments. The higher availability of N encouraged the carbohydrate synthesis, resulting in taller plant height in N applied treatments. The data in table 1 indicated that dry matter accumulation was slow up to 40 DAS, however it took a rapid growth rate and continued up to harvest. An increase in dry matter up to 80 DAS was related to more vegetative growth. No significant difference was found in dry matter accumulation up to 80 DAS due to irrigation treatments because of frequent rainfall up to 70 DAS however, a significant difference was found with irrigation regimes at harvest. The highest dry matter accumulation was found in the I<sub>1</sub> treatment, which was statistically similar to the I<sub>2</sub> treatment whereas in I<sub>3</sub>, dry matter accumulation was the lowest. Compared to lower irrigation levels, higher irrigation regimes' increased water availability may have facilitated the more rapid movement of assimilates from the source to the growing grains (Si *et al.*, 2020). So more dry matter was observed in I<sub>1</sub> and I<sub>2</sub> treatments compared to I<sub>3</sub> treatment. Nitrogen application created a significant effect on dry matter accu-

mulation at 40, 80 DAS, and harvest. At 40 DAS dry matter accumulation was found significant between the treatments. The highest dry matter accumulation was found in  $N_1$  and the lowest was observed in control. Increased dose of nitrogen application at basal and CRI stage helped to get more dry matter in  $N_1$ . At 80 DAS highest dry matter accumulation was found in  $N_1$  which was statistically at par with  $N_3$ . Nano-urea application at 40 DAS allowed the plant to rapidly increase its vegetative growth. Nitrogen is regarded as a crucial plant nutrient that plays a significant role in numerous physiological processes, including chlorophyll synthesis, the main absorber of light energy required for photosynthesis. Nitrogen application accelerated leaf area expansion, which led to higher photosynthates being accumulated and higher dry matter production. According to Man *et al.*, 2017, increase in LAI significantly results in increased biomass production. However, lower nitrogen management practices led to decreased dry matter accumulation because nitrogen-deficient soil (low in accessible nitrogen) may have impeded cell elongation, which stifled plant vegetative growth (Gupta *et al.*, 2019). At harvest, the highest dry matter accumulation was found in  $N_1$ , which was statistically at par with  $N_3$ ; both were better than  $N_2$  and  $N_4$ , but the lowest accumulation was observed in the control plot.

LAI increased rapidly after 40 DAS and the highest at 80 DAS, coinciding with the crop's flowering stages (Table 1). No significant difference was found in LAI due to irrigation treatments because of frequent rainfall up to 70 DAS. Nitrogen management in the form of prilled urea and nano-urea significantly affected LAI in both stages. At 40 DAS the highest LAI was observed in the  $N_1$  treatment while the lowest LAI was recorded in the  $N_0$  treatment (control plot).  $N_4$  treated plot showed higher LAI compared to  $N_2$  and  $N_3$ , which were statistically at par up to 40 DAS. After applying nano-urea at 45 DAS in  $N_3$  treatment, plants

developed more LAI than other nano-urea treatments. At 80 DAS in  $N_3$  LAI (3.58) was recorded which was more than  $N_0$ ,  $N_2$  and  $N_4$  but comparatively lower than  $N_1$ . Application of nano-urea at 60 DAS in  $N_2$  and  $N_4$  didn't help plants so much to increase the LAI. According to Kirchhoff, 2013, nitrogen availability systematically and significantly impacts chloroplast synthesis. Around 75% of nitrogen is devoted to synthesising the photosynthetic machinery, including thylakoid membranes and associated enzymes, in chloroplasts. Consequently, when more nitrogen was applied, leaves grew longer and wider, showing more veins and stomata, which indicates greater cell division and the creation of more cells. Lack of nitrogen caused leaves to grow smaller, mostly by lowering the number of cells. A lack of nitrogen has been linked to asymmetrical cell division, cell division terminating at various locations from the base of the leaf, decreased cell flow, small mature cell size, decreased cell elongation, and longevity.

A non-significant difference in flag leaf area was found between the different irrigation regimes due to the availability of soil moisture throughout the vegetative stages of the crop growth, however nano-urea based nitrogen management affected the flag leaf area significantly (Table 1). The highest flag leaf area was found with  $N_1$  whereas the lowest was found in  $N_0$  (control). Nitrogen being a constituent of amino acids, protein, and protoplast would directly influence flag leaf area by leaf expansion (length and breadth) resulting from cell division and cell enlargement at higher N rates (Hashim *et al.*, 2015). Higher nitrogen availability before the double ridge when the final leaf primordia were being initiated was important in determining the size of the flag leaf. Applying nano-urea at the active tillering stage (45 DAS) favoured the plant leaves to develop more vigorously compared to other nano-urea treated plots applied nano-urea at 60 DAS.

The irrigation regimes effect was non-significantly on

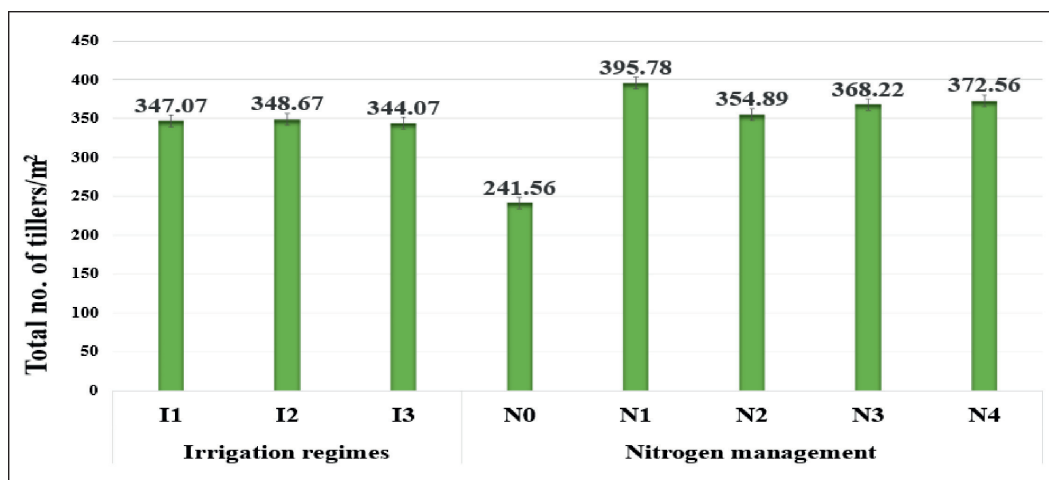


Fig. 1. Effect of nano-urea and irrigation regimes and nitrogen management on tiller count in wheat

**Table 1.** Effect of irrigation regimes and nitrogen management on growth parameters of wheat

Treatment	Plant Height (cm)		Leaf Area Index		Flag leaf area at flowering (cm <sup>2</sup> /leaf)	Dry matter accumulation (g/m <sup>2</sup> )		Root dry weight (g/m <sup>2</sup> )		
	40 DAS	80 DAS	40 DAS	80 DAS		40 DAS	Harvest	Maximum tillering (55 DAS)	Flowering stage (85 DAS)	
<i>Irrigation regimes</i>										
I <sub>1</sub>	27.0	90.7	1.19	2.95	27.03	81.38	584.38	937.37	35.5	68.75
I <sub>2</sub>	27.4	90.9	1.14	2.84	26.25	76.60	603.90	926.39	32.83	66.40
I <sub>3</sub>	28.4	88.9	1.18	3.06	28.87	81.96	607.83	786.77	33.25	69.91
SEM±	0.3	0.5	0.06	0.05	1.15	2.06	12.62	19.42	1.94	1.17
LSD (P≤0.05)	NS	NS	NS	NS	NS	NS	NS	76.24	NS	NS
<i>Nitrogen management practices</i>										
N <sub>0</sub>	18.9	57.0	0.59	1.75	15.27	39.06	262.64	274.69	17.78	42.44
N <sub>1</sub>	30.9	102.7	1.44	3.71	33.06	105.21	752.39	1202.94	48.16	85.67
N <sub>2</sub>	29.2	94.5	1.23	2.69	27.54	81.22	578.91	760.89	30.13	59.84
N <sub>3</sub>	29.5	99.4	1.22	3.58	31.52	82.06	731.46	1174.25	31.82	80.73
N <sub>4</sub>	29.5	97.4	1.36	3.32	29.51	92.27	668.19	1004.75	41.38	73.07
SEM±	0.2	0.5	0.02	0.08	0.33	1.84	11.08	19.59	0.80	0.60
LSD (P≤0.05)	0.6	1.4	0.06	0.22	1.22	5.37	32.34	57.19	2.20	1.80

(I<sub>1</sub>: 5 irrigations, I<sub>2</sub>: 3 irrigations, I<sub>3</sub>: 2 irrigations, I<sub>4</sub>: 1 irrigation; N<sub>0</sub>: control, N<sub>1</sub>: 100% RDN, N<sub>2</sub>: 50% RDN+1 NUS, N<sub>3</sub>: 50% RDN+2 NUS, N<sub>4</sub>: 75% RDN+1 NUS)

tillers/m<sup>2</sup> (Fig. 1). Frequent rainfall up to the crop's blossoming phases was the primary cause of this insignificant variation. The tillers/m<sup>2</sup> were greatly affected by nano-urea based nitrogen management practices. Due to insufficient N in the soil, the control plot had the fewest tillers/m<sup>2</sup> (241.56). Nitrogen was more readily available in nitrogen-applied plots which stimulated the synthesis of carbohydrates and led to more tillers per plant (Mukherjee, 2019). The N<sub>1</sub> (100% RDN) has the most tillers per square meter (395.78), slightly higher than N<sub>3</sub> (388.22). In N<sub>3</sub> treatment, nano-urea applied at 45 DAS (tillering stage), which guided the plant to produce more no. of tillers compared to other nano-urea treatments. Applying nano-urea at 60 DAS in N<sub>2</sub> and N<sub>4</sub> didn't help plants so much to increase the no. of tillers production. Sarkar *et al.* (2023) also reported that effective tillers in wheat were significantly higher with 100% RDN instead of nano-urea application. The observations on root dry matter were taken at the maximum tillering stage (50 DAS) and the flowering stage (Table 1) which indicated that root dry weight continued to increase with advancement in crop age and this increase was rapid up to the flowering stage. A non-significant difference in root weight was observed for the irrigation regime. The main reason is the availability of well-distributed moisture in soil at different growth stages due to rainfall up to the flowering stage. Nitrogen management practices significantly influenced the root dry weight of the plants in both stages. At the maximum tillering stage root dry weight was highest for N<sub>1</sub> (48.16 g/m<sup>2</sup>) and lowest for control (17.78 g/m<sup>2</sup>). Root dry weight found on N<sub>2</sub> and N<sub>3</sub> was statistically similar but comparatively lower than N<sub>4</sub> at this stage. The application of higher doses of nitrogen at basal and CRI was the main reason behind this (Kumar *et al.*, 2015). At the flowering stage maximum root dry weight was observed in N<sub>1</sub>. In N<sub>3</sub> root dry weight was slightly less than N<sub>1</sub>. In N<sub>3</sub> treatment, we applied nano-urea at 45 & 70 DAS guided the plant to generate more roots than other nano-urea treatments. Application of nano-urea at 60 DAS in N<sub>2</sub> and N<sub>4</sub> didn't help plants so much generate more roots by the crop. An increase in nitrogen application promotes more development of nodal roots in the soil. Also, it increases the density of roots within the soil profile which leads to more root dry weight by the plants where N was applied before completion of vegetative growth stages (Rasmussen *et al.*, 2015). From this experiment, irrigation regimes registered non-significant difference on all the crop

growth parameters which might be due to frequent rainfall up to flowering stage of crop. In nitrogen management practices, higher level of nitrogen should be applied at initial stages to give a boost to the growth parameters of wheat. Nano-urea should be applied at active growing stages of wheat to maintain the growth attributes at sufficient level. Foliar application of nano-urea was inept to meet 25 or 50% of RDN; hence, 100% RDN in 3 split doses was superior for enhancing the growth parameters of wheat.

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