



International Journal of Research in Agronomy

E-ISSN: 2618-0618
P-ISSN: 2618-060X
© Agronomy
NAAS Rating (2026): 5.20
www.agronomyjournals.com
2026; 9(7): 1632-1636
Received: 02-05-2026
Accepted: 08-06-2026

Bhagat Singh
Department of Agronomy, CCS
Haryana Agricultural University,
Hisar, Haryana, India

Sachin Kumar
Department of Agronomy, CCS
Haryana Agricultural University,
Hisar, Haryana, India

AK Dhaka
Department of Agronomy, CCS
Haryana Agricultural University,
Hisar, Haryana, India

Pooja Gupta Soni
Department of Agronomy, CCS
Haryana Agricultural University,
Hisar, Haryana, India

Renu Munjal
Department of Botany & Plant
Physiology, CCS Haryana
Agricultural University, Hisar,
Haryana, India

Corresponding Author:
Bhagat Singh
Department of Agronomy, CCS
Haryana Agricultural University,
Hisar, Haryana, India

Response of irrigated wheat to nitrogen management using nano and prilled urea

Bhagat Singh, Sachin Kumar, AK Dhaka, Pooja Gupta Soni and Renu Munjal

DOI: <https://www.doi.org/10.33545/2618060X.2026.v9.i7u.6173>

Abstract

Excessive reliance on conventional granular urea leads to substantial nitrogen losses and degraded nutrient use efficiency. To evaluate the potential of nano-fertilizers as a sustainable alternative, a two-year field experiment was conducted during *Rabi* season of 2021-22 and 2022-23 at CCS Haryana Agricultural University, Hisar, India, using wheat cultivar WH 1270 under irrigated conditions. The trial followed a randomized block design with 13 treatments evaluating varying nitrogen regimes and foliar sprays of nano urea and conventional 5% urea. The application of recommended nitrogen doses (150kg/ha) combined with two foliar sprays of nano urea at tillering and jointing stages yielded the highest grain yield during both years. RDN + two spray of nano urea at tillering and jointing recorded significantly higher effective tillers (443 and 415 per m²), grain yield (56.19 and 62.20 q/ha) and biological yield (146 and 151 q/ha) during first and second year of study and it was statistically comparable to RDN, RDN with one nano urea spray and RDN with two conventional 5% urea sprays. Supplementing RDN with two foliar sprays of nano urea or 5% conventional urea enhanced grain yield by 5.3% and 3.7% over RDN alone, respectively. Furthermore, nano urea treatments favorably impacted physiological parameters, demonstrating higher Normalized Difference Vegetation Index (NDVI) values and lower canopy temperatures.

Keywords: Nano, wheat, nitrogen and yield

1. Introduction

Wheat (*Triticum aestivum* L.) is the leading cereal crop cultivated during the *Rabi* season in India. It is hexaploid (6n = 42) species belongs to Poaceae family, which plays a crucial role for feeding approximately 4.5 billion people, supplying 20% of their daily intake of protein and calories (Shewry and Hey, 2015) ^[20]. Globally wheat is the leading cereal crop which constitutes nearly 30% of total cereal production and is an essential food for about close to 10 billion people in 43 different countries. The global wheat cultivated area is about 240 million hectares, producing an output of 777 million metric tonnes (FAO, 2023) ^[3]. Nevertheless, China stands out as the leading wheat producer worldwide, reaching a historic output of 137 million tonnes, with India following closely behind (110.55 million tonnes), Russia (91.5 million tonnes) and the USA (49.1 million tonnes) (USDA, 2024) ^[24], together they contribute about 58% of global wheat production which is around 449 million tonnes. In 2023-24, India recorded an unprecedented wheat output of 113.92 million tons from a cultivated area of 34.15 million hectares, achieving an average productivity of 3.31 tons per hectare (MoA and FW, 2024). Nutrient management plays a vital role in attaining self-sufficiency in food grain production. However, indiscriminate fertilizer application has led to increased nutrient usage and diminished profitability. The efficiency of conventional fertilizers has seen little improvement over the years, with nitrogen, phosphorus and potassium utilization rates remaining at approximately 30–35%, 18–20% and 35–40%, respectively (Umaret *et al.*, 2020) ^[23]. Nitrogen stands out as the most crucial and fundamental nutrient among all essential nutrients. It is a crucial nutrient necessary for the production of enzymes, DNA, RNA, amino acids and chlorophyll, making it essential for the growth and development of plants (Ohya, 2010) ^[11]. The efficiency of nitrogen utilization diminishes with increasing nitrogen application rates, primarily due to its vulnerability to losses through processes like leaching, denitrification and volatilization (Zhao *et al.*, 2006; Tana *et al.*, 2015) ^[27, 22]. The unbalanced and over-reliant use of

standard urea, comprising 46% nitrogen, with the primary focus on boosting productivity and profitability, has caused a reduction in the soil's effectiveness in responding to fertilizer applications (Ladha *et al.*, 2005) ^[9]. The Fertilizer Association of India has reported that the total consumption of urea in India was 34.18 million metric tons. The total amount comprised 25.08 million metric tons from domestic production and 9.14 million metric tons from imports.

In recent years, there has been a growing interest in nanotechnology, particularly in the application of nano-fertilizers aimed at optimizing their efficiency. Nano-fertilizers are essential for enhancing crop resilience against various stress factors, boosting disease resistance, preserving the genetic traits necessary for other crops and augmenting the active compounds within plants. By utilizing the unique attributes of particles sized between 1 and 100 nano meters, these fertilizers can significantly boost nutrient use efficiency (Seleiman *et al.*, 2020) ^[19]. Nano-fertilizers are characterized by their favourable properties, such as superior solubility, stability, effectiveness, controlled release mechanisms, targeted application, reduced environmental toxicity and ease of delivery and disposal. A recent evaluation of nano-fertilizers has confirmed their remarkable solubility, consistency, effectiveness, time-controlled release, targeted application and safe, easy methods for both delivery and disposal. The application of nanotechnology in agriculture has surfaced as a promising strategy for improving crop yields and reducing the environmental consequences associated with conventional farming methods. In this context, evaluating the efficacy of nano-urea on wheat growth dynamics, grain yield, and crop physiology provides critical insights into integrating modern agrotechnology with sustainable nutrient management.

2. Materials and Methods

The field experiment was conducted during *Rabi* season of 2021-22 and 2022-23 at Wheat & Barley Section Research Area, Department of Genetics and Plant Breeding, CCS Haryana Agricultural University, Hisar (Haryana) situated at 29°1'N Latitude and 75°46' E Longitude with a height of 215.2 meters above mean sea level. The soil of experimental field was low in available nitrogen (143.5 kg/ha), medium in available phosphorus (12.1 kg/ha) and high in available potassium (252.6 kg/ha) with 0.45% organic carbon. It was moderately alkaline in reaction with pH 7.8 and electrical conductivity of 0.28 dS/m. The experiment was conducted in randomized block design (RBD) with 13 treatments: [T₁ = Recommended N doses (1/3rd basal, 1/3rd CRI, 1/3rd tillering) + water spray at tillering (40-45 DAS) and jointing (60-65 DAS), T₂= RDN + one spray of nano urea at tillering, T₃= RDN + two spray of nano urea at tillering and jointing, T₄= RDN + two spray of urea (5%) at tillering and jointing, T₅= 75% N + water spray at tillering and jointing, T₆= 75% N + one spray of nano urea N at tillering, T₇= 75% N + two spray of nano urea at tillering and jointing, T₈= 75% N + two spray of 5% urea at tillering and jointing, T₉= 50% N + water spray at tillering and jointing, T₁₀= 50% N + one spray of nano urea at tillering, T₁₁= 50% N + two spray of nano urea at tillering and jointing, T₁₂= 50% N + two spray of 5% urea at tillering and jointing and T₁₃= Control (without N only)] and each treatment was replicated thrice.

Wheat variety WH 1270 was sown with a seed rate of 100 kg/ha on 11th and 12th November during 2021 and 2022, respectively. Full dose of phosphorus and potash and 1/3rd nitrogen was applied as basal dose as per treatments and the remaining 2/3rd nitrogen as 1/3rd at first irrigation and 1/3rd at second irrigation wherever required as per treatment while recommended P and K were applied in all the treatments. Nano urea was sprayed @ 4 ml/litre

of water with a quantity of water 400 l/ha.

The process of data collection encompassed the measurement of various yield parameters including effective tillers/m², grains/earhead, 1000 grains weight, grain yield and biological yield (q/ha) at the harvest stage, of randomly selected plants within each plot. Measurement of chlorophyll was done by using SPAD meter whereas, canopy temperature was measured using infrared thermometer.

3. Results and Discussion

3.1 Plant height

The perusal of plant height (Table 1) data recorded at maturity revealed that the significantly higher plant height (94.96 and 97.00 cm) was recorded with treatment RDN + two spray of urea (5%) at tillering and jointing as compared to other treatments, but was statistically at par with T₁, T₂, T₃, T₆, T₇ and T₈ during 2021-22 and 2022-23, respectively. It may be due to more availability and uptake of nitrogen which enhanced the process of synthesis of protoplasm, expansion, cell division, vigorous plant growth (Sisodiya *et al.*, 2024, Jadhav *et al.*, 2023 and Kashyap and Bainade, 2022) ^[21, 6, 7].

3.2 Effective tillers/m²

The data mentioned in the table 1, showed that different treatments had a significant effect on the numbers of effective tillers/m² and significantly higher effective tillers/m² was recorded in the treatment RDN + two spray of nano urea at tillering and jointing in 2021-22 (443) and with RDN + two spray of urea (5%) at tillering and jointing in 2022-23 (416) as compared to other treatments except T₁, T₂ and T₃ during both the years. The increase in effective tillers/m² might be associated with higher nitrogen availability and prolonged nutrient release capability of nano fertilizers, which ensures constant supply of nutrients and positively influences plant growth. The application of nano urea resulted in enhanced uptake of nitrogen through both leaves and roots due to its better absorption. This resulted in more synthesis of carbohydrates into amino acids and proteins, which resulted in increased cell division and elongation. These results are in conformity with the findings of by Rani *et al.* (2024) ^[14], Rawateet *et al.* (2022) ^[15], Yadav *et al.* (2023) ^[26] and Sarkar *et al.* (2023) ^[18] have reported similar findings.

3.3 Grains/earhead

The results presented in Table 1, showed that grains/earhead didn't showed any significant difference during the year 2021-22 but was recorded highest with the treatment RDN + two spray of nano urea at tillering and jointing (33.38) followed by RDN + two spray of urea (5%) at tillering and jointing (33.13). However, during 2022-23 maximum grains/earhead was recorded with RDN + two spray of urea (5%) at tillering and jointing (57.80), which was statistically at par with T₁, T₂, T₃ and T₇. Foliar supplementation of nitrogen enhances chlorophyll synthesis, leaf area index (LAI) and photosynthetic. This leads to greater accumulation of photo-assimilates and efficient partitioning of carbohydrates toward the developing earhead (sink), resulting in higher grains/earhead. These results are similar with the findings of Gooding and Davies (1992) ^[4] and Kumar *et al.* (2021) ^[8].

3.4 1000 grains weight

The perusal of data presented in Table 1, showed that 1000 grains weight didn't influenced significantly by different treatments during the year 2021-22 but was recorded highest with the treatment control (41.11) followed by 50% N + water spray at tillering and jointing (40.30). However, during 2022-23 1000 grains weight showed a significant variation among the

treatments and was recorded highest with control (40.80) which was at par with T₉, T₁₁ and T₁₂. Nitrogen application increases tiller survival, effective panicles/unit area and the number of grains/earhead which ultimately results in increase in test weight of grains. These results are in conformity with Zhang *et al.* (2024)^[28] and Vicentin and Canales (2024)^[25].

3.5 Grain yield

The data given in the table 2, showed that different treatments had a significant effect on the grain yield of wheat and higher grain yield (56.19 and 62.20 q/ha) was recorded with treatment T₃ (RDN + two spray of nano urea at tillering and jointing) which was significantly higher than other treatments except T₁ (54.25 and 59.06q/ha), T₂ (55.03and 60.13 q/ha) and T₄ (55.95and 61.27 q/ha) in 2021-22 and 2022-23, respectively. This may be due the synergistic effect of nano fertilizer in combination with prilled urea that improved nutrient absorption efficiency, nutrient translocation, enhanced photosynthesis and finally increased the economic and biological yield. With the increase in growth and yield parameters due to foliar application of nano urea spray, there was increase in overall yield. These results are similar with the findings of Sisodiya *et al.* (2024)^[21], Rani *et al.* (2024)^[14], Sarkar *et al.*, (2023)^[18], Ojha *et al.* (2023)^[12] and Al-Juthery *et al.* (2018)^[1], Rahman *et al.* (2019)^[13] and Al-Shamary and Ansari (2022)^[2].

3.6 Biological yield

The perusal of the data presented in the table 2, showed that different treatments had a significant effect on the biological yield and significantly higher biological yield (146 and 151 q/ha) was recorded in treatment T₃ (RDN + two spray of nano urea at tillering and jointing) which was significantly higher than other treatments except T₁ (142 and 147 q/ha), T₂ (145 and148q/ha), T₄ (146 and149 q/ha) and T₇ (134 and 141q/ha) during 2021-22 and 2022-23, respectively. Nitrogen is a crucial component in plant tissues which plays vital role in cell division and cell elongation which reflected its synergistic effect on different growth parameters viz., plant height, number of leaves and dry matter accumulation (Srivani *et al.*, 2022). Furthermore, the appropriate supply of nitrogen enhanced the meristematic activity and photosynthetic area which resulted in improved production and accumulation of more photosynthates which collectively resulted in higher yield. These results are in conformity with Sisodiya *et al.* (2024)^[21], Samui *et al.* (2022)^[17], Sarkar *et al.* (2023)^[18], Ojha *et al.* (2023)^[12] and Al-Juthery *et al.* (2018)^[1].

3.7 Harvest index

The data mentioned in table 2, revealed that the harvest index (%)

didn't showed any significant variation among the treatments but was recorded highest (38.49 and 41.19%) in treatment RDN + two spray of nano urea at tillering and jointing followed by RDN + two spray of urea (5%) at tillering and jointing (38.32 and 41.12%) during 2021-22 and 2022-23, respectively.

3.8 Canopy Temperature (°C)

The data presented in the table 3, showed that canopy temperature at 15 DAA (Days after anthesis) ranged from (21.1-25.5 °C and 24.0-26.9 °C) during 20221-22 and 2022-23, respectively which was found maximum with control (26.5 and 26.9 °C) and minimum (21.1 °C) with RDN + two spray of nano urea at tillering and jointing in 2021-22 and RDN + two spray of urea (5%) at tillering and jointing (24 °C) in 2022-23. Nitrogen plays a fundamental role in stomatal regulation and guard cell function. Foliar application of nano urea or conventional urea at tillering and jointing improves leaf N concentration, chlorophyll content and stomatal opening. Higher stomatal conductance facilitates greater transpiration rates, which produces transpirational cooling effect. This significantly lowers the canopy surface temperature relative to ambient air (Gupta, 2023)^[5].

3.9 NDVI

The perusal of the data presented in the table3, showed that NDVI at 15 days after anthesis (DAA) of different treatments ranged from (0.72-0.81 and 0.61-0.72) during 20221-22 and 2022-23, respectively. Significantly higher NDVI was found with treatment RDN + two spray of urea (5%) at tillering and jointinghaving (0.81) and equal in T₃(0.72) and T₄ (0.72) whereas, lowest NDVI value was recorded in control (0.72 and 0.81) in 2021-22 and 2022-23, respectively. Applying supplemental nitrogen via foliar sprays at critical vegetative stages (tillering and jointing) boosts leaf nitrogen content. This extra nitrogen prevents premature chlorophyll degradation of flag leaves (Saleem *et al.*, 2010)^[16].

3.10 SPAD Chlorophyll content

SPAD chlorophyll content (Table 3) at 15 days after anthesis (DAA) of different treatments ranged from (46.24-51.88 and 43.6-51.2) during 20221-22 and 2022-23, respectively. Significantly higher (51.88 and 51.2) chlorophyll content was found with treatment RDN + one spray of nano urea at tillering having whereas, lowest chlorophyll content was recorded in control (44.78 and 43.6) in 2021-22 and 2022-23, respectively. Applying supplemental nitrogen via foliar sprays at critical vegetative stages (tillering and jointing) boosts leaf nitrogen content. This extra nitrogen prevents premature chlorophyll degradation of flag leaves (Saleem *et al.*, 2010)^[16].

Table 1: Effect of different treatments on plant height and yield attributes of wheat

Treatments	Plant height (cm)		Effective tillers/m ²		Grains/Earhead		1000-grains weight (g)	
	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23
T ₁	92.29	95.00	425	410	32.63	56.87	39.14	37.00
T ₂	92.60	95.40	435	414	33.03	57.03	38.30	36.86
T ₃	93.90	96.33	443	415	33.38	57.67	38.03	37.21
T ₄	94.96	97.00	440	416	33.13	57.80	38.39	37.60
T ₅	90.70	92.20	382	372	32.10	53.53	39.28	37.35
T ₆	91.20	92.47	389	373	32.17	54.30	39.72	37.32
T ₇	91.85	94.23	397	382	32.88	54.93	39.25	37.76
T ₈	91.78	93.40	389	380	32.42	54.00	38.97	38.20
T ₉	88.40	89.47	335	330	31.16	47.87	40.30	39.90
T ₁₀	88.27	89.00	350	335	30.93	48.03	39.96	38.51
T ₁₁	88.78	90.40	366	338	30.55	48.57	40.11	39.81
T ₁₂	90.42	91.13	362	334	30.36	49.13	40.28	39.45
T ₁₃	82.60	84.87	285	292	29.41	46.27	41.11	40.80
LSD (p=0.05)	4.06	4.73	34	29	NS	3.14	NS	2.07

Table 2: Effect of different treatments on grain yield (q/ha), biological yield and harvest index (%) of wheat

Treatments	Grain yield (q/ha)		Biological yield (q/ha)		Harvest index (%)	
	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23
T ₁	54.25	59.06	142	147	38.20	40.18
T ₂	55.03	60.13	145	148	37.35	40.63
T ₃	56.19	62.20	146	151	38.49	41.19
T ₄	55.95	61.27	146	149	38.32	41.12
T ₅	47.93	54.00	128	135	37.45	40.00
T ₆	49.39	54.93	131	137	37.70	40.09
T ₇	50.95	56.06	134	141	38.02	39.76
T ₈	49.12	56.55	130	140	37.78	40.39
T ₉	41.91	45.83	116	116	36.13	39.51
T ₁₀	43.16	47.11	119	120	36.27	39.26
T ₁₁	44.52	48.46	124	123	35.90	39.40
T ₁₂	44.15	48.30	122	123	36.19	39.27
T ₁₃	34.32	35.10	99	90	34.67	39.00
LSD (p=0.05)	4.66	3.92	12	10	NS	NS

Table 3: Effect of different treatments on physiological parameters of wheat

Treatment	Canopy Temperature (°C) at 15 DAA		NDVI at 15 DAA		SPAD Chlorophyll Content at 15 DAA	
	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23
T ₁	23.4	24.4	0.78	0.69	51.26	49.8
T ₂	22.8	24.6	0.80	0.70	51.88	51.2
T ₃	21.1	24.2	0.79	0.72	50.8	50.0
T ₄	21.9	24.0	0.81	0.72	50.96	50.2
T ₅	21.8	25.9	0.80	0.68	48.06	47.4
T ₆	23.9	25.7	0.78	0.69	49.32	47.8
T ₇	22.8	25.1	0.79	0.69	48.52	47.8
T ₈	22.8	25.1	0.79	0.70	50.88	49.6
T ₉	24.4	26.1	0.75	0.67	46.24	44.8
T ₁₀	25.0	26.2	0.73	0.68	49.51	47.2
T ₁₁	25.5	25.5	0.73	0.67	48.96	48.4
T ₁₂	25.3	25.7	0.74	0.66	47.84	47.1
T ₁₃	26.5	26.9	0.72	0.61	44.78	43.6
Range	21.1 – 26.5	24.0 – 26.9	0.72 - 0.81	0.61 - 0.72	46.24-51.88	43.6 – 51.2

4. Conclusion

Application of recommended dose of nitrogen (RDN) with two sprays of nano urea or two sprays of urea (5%) or one spray of nano urea were produced statistically similar grain yield with recommended dose of nitrogen (RDN) without any spray. The addition of two sprays of nano urea and urea at tillering and jointing stage with RDN brought an increase of 5.3 and 3.7% in grain yield over RDN, respectively.

References

- Al-Juthery HW, Habeeb KH, Altaee FJK, Al-Taey DK, Al-Tawaha ARM. Effect of foliar application of different sources of nano-fertilizers on growth and yield of wheat. *Biosci Res.* 2018;(4):3976-3985.
- Al-Shamary AJZ, Al-Ansari AMS. Response of growth and productivity of wheat cultivars (*Triticum aestivum* L.) to nano-N and urea fertilizer. In: IOP Conference Series: Earth and Environmental Science. Vol. 1060. Bristol: IOP Publishing; 2022. p. 012040.
- Food and Agriculture Organization of the United Nations. The state of food and agriculture 2023: Revealing the true cost of food to transform agrifood systems. Rome: FAO; 2023.
- Gooding MJ, Davies WP. Foliar urea sprays on wheat: A review. *Fert Res.* 1992;32(2):209-222.
- Gupta PK. Foliar nano-fertilization enhances physiological performance, stomatal regulation, and thermal cooling in wheat. *Front Plant Sci.* 2023;16:514-521.
- Jadhav AB, Majik ST, Gosavi AB, Patil AV. Synthesis, characterization and impact of nano-urea on growth and yield of wheat in Inceptisol. *Int J Environ Clim Change.* 2023;13(12):973-996.
- Kashyap C, Bainade SP. Leaf Colour Chart (LCC) based nano urea fertilization in maize (*Zea mays* L.). *Biol Forum Int J.* 2022;14(2A):184-187.
- Kumar Y, Tiwari KN, Nayak AK, *et al.* Nano urea: A novel solution for sustainable agriculture and enhanced crop productivity. *J Plant Nutr.* 2021;44(18):2730-2745.
- Ladha JK, Pathak H, Krupnik TJ, Six J, van Kessel C. Efficiency of fertilizer nitrogen in cereal production: Retrospects and prospects. *Adv Agron.* 2005;87:85-156.
- Ministry of Agriculture and Farmers Welfare. Agricultural statistics at a glance. New Delhi: Economics, Statistics & Evaluation Division, Department of Agriculture & Farmers Welfare, Government of India; 2024.
- Ohyama T. Nitrogen as a major essential element of plants. *Nitrogen Assim Plants.* 2010;37:1-17.
- Ojha A, Singh R, Sinha J. Effect of nano urea and foliar spray of urea on growth and yield of wheat (*Triticum aestivum* L.). *Int J Environ Clim Change.* 2023;13(11):474-481.
- Rahman IU, Aftab RA, Zafar I, Shafiul M. Foliar application of plant mineral nutrients on wheat: A review. *RRJAAS.* 2014;3(2):19-22.
- Rani G, Lata S. Effect of nano urea on growth and yield of wheat (*Triticum aestivum* L.) under irrigated condition. *Int J Res Agron.* 2024;7(8):10-35.
- Rawate D, Patel JR, Agrawal AP, Agrawal HP, Pandey D, Patel CR, *et al.* Effect of nano urea on productivity of wheat

- (*Triticum aestivum* L.) under irrigated condition. *Pharma Innov.* 2022;11:1279-1282.
16. Saleem MF, Ma BL, Voldeng H, Wang TC. Nitrogen nutrition on leaf chlorophyll, canopy reflectance, grain protein and grain yield of wheat varieties with contrasting grain protein concentration. *J Plant Nutr.* 2010;33(11):1681-1695.
 17. Samui S, Sagar L, Sankar T, Manohar A, Adhikary R, Maitra S, *et al.* Growth and productivity of rabi maize as influenced by foliar application of urea and nano-urea. *Crop Res.* 2022;57(3):136-140.
 18. Sarkar A, Singh T, Mondal A, Kumar S, Das TK, Kaur R, *et al.* Effect of nano-urea and herbicides on yield and yield attributes of wheat (*Triticum aestivum*). *Indian J Agron.* 2023;68(1):97-100.
 19. Seleiman MF, Almutairi KF, Alotaibi M, Shami A, Alhammad BA, Battaglia ML. Nano-fertilization as an emerging fertilization technique: Why can modern agriculture benefit from its use. *Plants.* 2020;10(1):2.
 20. Shewry PR, Hey SJ. The contribution of wheat to human diet and health. *Food Energy Secur.* 2015;4(3):178-202.
 21. Sisodiya A, Nayak S, Singh S, Yadav K, Singh N, Kamboj DS. Evaluating nano-urea as a substitute for prilled urea in cultivation. *Int J Agric Environ Biotechnol.* 2024;17:509-517.
 22. Tana T, Dalga D, Sharma JJ. Effect of weed management methods and nitrogen fertilizer rates on grain yield and nitrogen use efficiency of bread wheat (*Triticum aestivum* L.) in southern Ethiopia. *East Afr J Sci.* 2015;9(1):15-30.
 23. Umar W, Ayub MA, Rehman MZU, Ahmad HR, Farooqi ZUR, Shahzad A, Rehman U, Mustafa A, Nadeem M. Nitrogen and phosphorus use efficiency in agroecosystems. In: *Resource use efficiency in agriculture.* Singapore: Springer; 2020. p. 213-257.
 24. U.S. Department of Agriculture. World Agricultural Outlook Board, Office of the Chief Economist & Economic Research Service. Washington (DC): U.S. Department of Agriculture; 2024.
 25. Vicentin L, Canales J. The trade-off between grain weight and grain number in wheat is explained by the overlapping of key phases determining major yield components. *Plant Commun.* 2024;15(6):101166.
 26. Yadav SK, Khan MA, Prajapati SK, Kumar P, Verma S, Patel K, *et al.* Foliar application of nano urea and boron on growth, yield attributes and yield in wheat (*Triticum aestivum* L.). *Environ Ecol.* 2023;41(2):883-890.
 27. Zhao RF, Chen XP, Zhang FS, Zhang H, Schroder J, Römheld V. Fertilization and nitrogen balance in a wheat-maize rotation system in North China. *Agron J.* 2006;98(4):938-945.
 28. Zhang M. Trade-offs between yield components and grain-filling characteristics of cereals in response to nitrogen fertilization. *Agron J.* 2024;116:812-819.