

Effect of nano fertilizers on growth and yield of wheat (*Triticum aestivum* L.)

ABSTRACT

A field experiment was conducted at Instructional Farm, College of Agriculture, Jodhpur during two consecutive *rabi* seasons of 2021-22 and 2022-23 to investigate the “Effect of nano fertilizers on yield of wheat (*Triticum aestivum* L.). The field experiment was tested in randomized complete block design (RCBD) with fourteen treatments replicated thrice. Results showed that the application of 100% recommended dose of fertilizer (RDF) + seed treatment (ST) with nano phosphorus and two foliar sprays of nano nitrogen at 35 and 55 days after sowing (DAS) was found the most effective treatment with recorded highest number of tillers (431/m²), length of spike (17.03 cm), number of spikes (414 /m²), number of grains (45.24 /spike), test weight (46.32) and grain yield (4399 kg/ha) on pooled basis. However, this treatment was found statistically at par with treatments of 100 per cent RDF + 2 foliar sprays (FS) of nano nitrogen at 35 and 55 DAS, 100% RDF + FS of nano phosphorus at 35 DAS, 75% RDF + ST with nano phosphorus and 2 foliar spray of nano nitrogen at 35 & 55 DAS but significantly superior over other treatments.

Key words: Foliar spray, Nano fertilizer, Seed treatment, Wheat and Yield

1. INTRODUCTION

Wheat (*Triticum aestivum* L.) is the most important crop among the cereals. It belongs to family Poaceae and originated from the Middle-East region of Asia. Wheat has a global significance as it is staple food for millions of people and supplies 20 per cent of the food calories for World's population. In India, it is the second staple food crop next to rice contributing about 32 per cent of the total food grain production. It is the cheapest source and supplier of the calories and protein for healthy diet [1]. Wheat straw is also a major source of fodder for the animal population of the country. Wheat grain contains starch (60-90%), protein (11-16.5%), fat (1.5-2%), inorganic ions (1.2-2%), vitamins B complex and E [2]. In India, wheat stands second position in area and production, but first in productivity amongst all the cereals with acreage, production and productivity of 31.23 million hectares, 112.92 million tonnes and 3615 kg/ha, respectively [3]. In Rajasthan, wheat crop covers an area of 27.85 lakh hectares with an annual production of 10.41 million tonnes and an average productivity of 3739 kg/ha which is slightly higher than national average. Rajasthan state is on fifth position in wheat production after Uttar Pradesh, Punjab, Haryana and Madhya Pradesh [4]. The application of fertilizers in the crop fields is a common practice for increasing the crop production to fulfill the global demand of food [5]. Meanwhile, excess use of mineral fertilizers is unsafe due to increase the pollution issues. However, conventional fertilizers don't provide the required results because most of the nutrients don't reach at the target site due to losses by evaporation, leaching, volatilization, erosion, run off and nutrients photolytic deprivation [6&7]. The cultivation of wheat is increasing, it requires heavy fertilization. Increasing cost of fertilizers is main cause of concern as most of fertilizers are imported in India. Besides, the use of nitrogen, phosphorus and potassic fertilizers are seen with lower nutrient use efficiency (NUE) which ranges from 20 to 50 per cent for nitrogen, 10-25 per cent for phosphorus and 70-80 per cent potassium [8&9]. Improvement of NUE is needed for better cropping systems, supporting the sustainable agricultural production systems and increasing soil quality components [10]. Nano-materials differ from conventional materials having specific composition with unique property like small size of particle with

Comment [A1]: Experimental treatments should be mentioned in the abstract.

Comment [A2]: With three replicates for each treatment.

Comment [A3]: The differences were not significant.

high surface area, high reactivity and catalytic activity [11]. A small delivery system of nano fertilizer is seen because of its multidisciplinary characters like remotely coordinated, a specific and targeted approach and release nutrient slowly or in controlled way which helps to dodge the biological barriers [12]. Nano-technology has gained popularity in the agricultural sector in recent decades due to the invention of nano fertilizers that enhances nutrient use efficiency and minimizing losses. Many researchers have witnessed that it is a boon for high crop production, so the present research work done on effect of nano fertilizers on growth and yield of wheat (*Triticum aestivum* L.).

Comment [A4]: The reference study is not sufficient and should be expanded.

2. MATERIALS AND METHODS

2.1 Experimental site

The experiment was carried out at Instructional Farm, College of Agriculture, Jodhpur during rabi seasons of 2021-22 and 2022-23. Geographically, Jodhpur is situated between 26° 15' N to 26° 45' North latitude and 73° 00' E to latitude 73° 29' East longitude at an altitude of 231 meter above mean sea level. The soil was loamy sand in texture, slightly alkaline in reaction (pH 7.8), low in organic carbon (0.14%) and medium in available nitrogen (175 kg/ha), medium in available phosphorus (24.2 kg/ha) and high in availability potash (325.0 kg/ha).

2.2 Experimental treatments

The field experiment was laid out in randomized complete block design (RCBD) with fourteen treatments replicated thrice. The treatments comprised of T₁-100% RDF + two foliar spray of nano N at 35 & 55 DAS, T₂-100% RDF + foliar spray of nano P at 35 DAS, T₃-100% RDF + ST with nano P at 5 ml/kg seed and two foliar spray of nano N at 35 & 55 DAS, T₄-75% RDF + two foliar spray of nano N at 35 & 55 DAS, T₅-75% RDF + foliar spray of nano P at 35 DAS, T₆-100% RDF + ST with nano P at 5 ml/kg seed and two foliar spray of nano N at 35 & 55 DAS, T₇-50% RDF + two foliar spray of nano N at 35 & 55 DAS, T₈-50% RDF + foliar spray of nano P at 35 DAS, T₉-50% RDF + ST with nano P at 5 ml/kg seed and two foliar spray of nano N at 35 & 55 DAS, T₁₀-Foliar spray of nano P at 35 DAS + two foliar spray of nano N at 35 & 55 DAS, T₁₁-ST with nano P at 5 ml/kg seed + foliar spray of nano P at 35 DAS + two foliar spray of nano N at 35 & 55 DAS, T₁₂- ST with nano P at 5 ml/kg seed + two foliar spray of nano N at 35 & 55 DAS, T₁₃-100% RDF through conventional fertilizers and T₁₄-Control. In accordance with the treatments, recommended doses of nitrogen, phosphorus and potassium fertilizers were given as basal application at the time of sowing through urea, di-ammonium phosphate (DAP) and murate of potash (MOP). Specifically, half of the prescribed nitrogen quantity was applied as a basal application while the remaining amount of nitrogen top dressed within the standing crop through urea at the time of the first irrigation. As per treatments, ST was done with nano DAP at 5 ml/kg of seed with required quantity of water to form thin film on seed surface and then dried in shade. Thereafter, sowing was done in each marked plots. The FS of nano N and P were done as per treatment combination. The foliar sprays of nano urea at 4 ml/L and nano DAP at 2 ml/L water was applied as per scheduled treatments. The first spray of nano urea was applied at 35 DAS and second at 55 DAS. FS of nano DAP was applied at 35 DAS.

Comment [A5]: Arrange the experimental treatments vertically and each treatment gets its own number.

- 1
- 2
- 3

3. RESULTS AND DISCUSSION

Data revealed that application of 100% RDF + ST with nano P and 2 foliar spray of nano N at 35 & 55 DAS recorded highest no. of tillers/m², length of spike, no. of spikes/m², no. of grains/spike, test weight which was statistically at par with 100% RDF + 2 FS of nano N at 35 and 55 DAS, 100% RDF + FS of nano P at 35 DAS, 75% RDF + ST with nano P and 2 foliar spray of nano N at 35 & 55 DAS. These improvements were observed in yield attributes such as tillers/m², number of spikes/m², spike length, number of grains/spike and test weight. The pooled data (Table 1) further confirms that this specific treatment led to a

Comment [A6]: The results and discussion should be divided into paragraphs.

remarkable increase of 171.1% in the number of tillers compared to the control plots. This notable effect can be attributed to the synergy between conventional fertilizer and nano fertilizer, which enhances nutrient absorption by plant cells, ultimately promoting optimal growth and metabolic processes like photosynthesis. This, in turn, results in higher accumulation and translocation of photosynthates to economically important plant parts, leading to an increased number of reproductive tillers. Another reason for the improved yield attributes could be the increased availability of nutrients, which facilitates faster translocation of photosynthates from leaves to sink sites, such as spikes and grains, through the stem. This results in longer and heavier spikes with more grains per spike. The nano fertilizers stimulated biological and enzymatic reactions while regulating hormone levels, creating favorable conditions for the accumulation of the necessary dry materials for pollination and fertilization. They might have reduced the rate of ovarian abortion, ultimately promoting pollination and fertilization, which results in a higher number of grains per spike. Besides their nutritional role, availability of nano nitrogen might have influenced hormone regulation, particularly auxin at the top of the spike. Cytokinin play a role in preventing the transfer of auxin from older to newer grains, thereby increasing grain set in the spike, which is reflected through increased number of grains per spike. These findings are in line with previous studies conducted by [13,14,15&16]. Results (Table 2) indicated that 100% RDF + ST with nano P and 2 FS of nano N at 35 & 55 DAS produced maximum grain, straw and biological yield which was statistically at par with treatments applied with 100% RDF + 2 FS of nano N at 35 and 55 DAS, 100% RDF + FS of nano P at 35 DAS and 75% RDF + ST with nano P and 2 FS of nano N at 35 & 55 DAS but remained significantly superior over treatments applied with 50% RDF in combination with nano fertilizers. Application of ST with nano P + 2 FS of nano N at 35 and 55 DAS recorded grain yield of 2294 kg/ha and when this treatment was super imposed with 50, 75 and 100% RDF, the grain yield was further improved by 54.4, 72.8 and 91.7%, respectively. The treatment of 50% RDF+ ST with nano P and 2 FS of nano N at 35 & 55 DAS significantly improved the grain yield by 881 and 1940 kg/ha over FS of nano P at 35 DAS + 2 FS of nano N at 35 and 55 DAS and control, respectively. This improvement can be attributed to high efficiency of fertilizer/nutrients utilization when they are applied in nano form combined with RDF. Various factors influence grain yield which are genotypic variations, environmental conditions and agronomic practices such as fertilization. Sahu *et al.* (2023) discovered that the application of foliar sprays of nutrient solutions at distinct growth stages, in conjunction with the judicious application of recommended fertilizer quantities and nano-diammonium phosphate (nano DAP), collectively contributed to a notable enhancement in yield. Nano form of fertilizers may be attributed to the superior absorption, interception and utilization of phosphorus. Nano P exhibited slow-release characteristic throughout the growth period, which consequently elevated chlorophyll synthesis and leads to a substantial accumulation of biomass yield. Liu and Lal's (2014) findings indicated a remarkable growth rate enhancement of 32.6 and 20.4% in seed production compared to the scenarios where no nano fertilizers were applied [17]. Indeed, recent studies by Velmurugan *et al.* (2021) and Sahu *et al.* (2022) have demonstrated that nano fertilizers performed better than commercial urea in different crops [18&19]. These findings are in close conformity with the results reported by [16,20,21,22&23].

Conclusion

On the basis of two years experimentation, it can be concluded that wheat crop can be fertilized with 100% RDF (90 kg N/ha, 40 kg P₂O₅ and 20 kg K₂O/ha) along with seed treatment with nano P @ 5 ml/kg of seed and two foliar spray of nano N @ 4 ml/L of water at 35 & 55 DAS for higher production.

Comment [A8]: The conclusion should be formulated in a more convincing and attractive manner.

REFERENCES

1. Heyne EG. Wheat and wheat improvement. 2nd ed. Madison, Wisconsin, U.S.A.;1987.
2. Rueda Ayala, Rasmussen VP, Gerhards JR, Fournaise, NE. The influence of post-emergence weed harrowing on selectivity, crop recovery and crop yield in different growth stages of winter wheat. *Weed Research*. 2011;51(5):478-488.
3. IIWBR. Indian Institute of Wheat and Barley Research, Karnal; 2024. (Website: <https://iiwbr.icar.gov.in> retrieved on dated 16-08-2024).
4. Govt. of Rajasthan. Second Advance Estimates of Area, Production and yield of crops in respect of Rajasthan State for the year 2023-24; 2024.
5. Chhipa H. Nano fertilizers and nano pesticides for agriculture. *Environmental Chemistry Letters*. 2017;15(1):15-22.
6. Manjunatha SB, Biradar DP, Aladakatti YR. Nano-technology and its applications in agriculture: A review. *Journal of Farm Sciences*. 2016;29(1):1-13.
7. Ram M, Kumhar BL, Kumar M, Meena RC and Meena DS. Comparative assessment of urea and nano urea on growth and yield of pearl millet. *Ecology, Environment & Conservation*. 2023;29:S203-S206.
8. Shaviv A. Advances in controlled release of fertilizers. *Advanced Agronomy Journal*. 2000;71:1-49.
9. Chinnamuthu CR, Boopathi PM. Nano-technology and agro-ecosystem. *Madras Agricultural Journal*. 2009;96:17-31.
10. Mahanta N, Dambale A, Rajkhowa M. Nutrient use efficiency through nano fertilizers. *International Journal of Chemical Studies*. 2019;7(3):2839-2842.
11. Verma H, Kapoor A. Agro-nanotechnology: an agricultural paradigm. 2020;1-24.
12. Nair R, Varghese S, Nair B, Maekawa T, Yoshida Y, Kumar S. Nanoparticulate material delivery to plants. *Plant Science*. 2010;179:154-163.
13. Aziz HMM, Hasaneen MNA, Omer AM. Nano chitosan-NPK fertilizer enhances the growth and productivity of wheat plants grown in sandy soil. *Spanish Journal of Agricultural Research*. 2016;14(1):1-11.
14. Khospeyak S, Haghi RS, Ahmadiyan A. The effect of application of nano organic fertilizer and nitrogen fertilizer on yield, yield components and essential oil content of fennel. *Iranian Journal of Field Crop Research*. 2016;14(4):775-787.
15. Rani B, Zalawadia NM, Buha D, Rushang K. Effect of different levels of chemical and nano nitrogenous fertilizers on content and uptake of N, P, K by sorghum crop cv. Gundari. *Journal of Pharmacognosy and Phytochemistry*. 2019;8(5):454-458.
16. Attri M, Sharma N, Sharma BC. Effect of foliar application of nano urea on productivity and profitability of fine rice under irrigated subtropics of Jammu region. *Indian Journal of Ecology*. 2022;49(5):1935-1938.
17. Liu R, Lal R. Synthetic apatite nano-particles as a phosphorus fertilizer for soybean (*Glycine max*). *Environmental Science*. 2014;4:1-18.
18. Velmurugan A, Subramanil T, Bommayasamy N, Ramakrishna MK, Swarnam TP. Effect of foliar application of nano urea (liquid) on Rice (*Oryza sativa* L.). *Journal of the Andaman Science Association*. 2021;26(2):76-81.
19. Sahu TK, Kumar M, Kumar N, Chandrakar T, Singh DP. Effect of nano urea application on growth and productivity of rice (*Oryza sativa* L.) under midland situation of Bastar region. *The Pharma Innovation Journal*. 2022;11(6):185-187.
20. AlJuthery HW, Habeeb KH, Altaee FJK, AlTaey DK, AlTawaha ARM. Effect of foliar application of different sources of nano fertilizers on growth and yield of wheat. *Bioscience Research*. 2018;4:3976-3985.
21. Kumar Y, Tiwari KN, Nayak RK, Rai A, Singh SP, Singh AN, Kumar Y, Tomar H, Singh T, Raliya R. Nano fertilizers for increasing nutrient use efficiency, yield and

- economic returns in important winter season crops of Uttar Pradesh. Indian journal of Fertilizers. 2020.16(8):772-786.
22. Meena RH, Jat G, Jain D. Impact of foliar application of different nano fertilizers on soil microbial properties and yield of wheat. Journal of Environmental Biology. 2021. 42: 302-308.
 23. Ranjan P, Kumar B, Mala A, Priyadarshi S, Shri A, Lal B, Narayan A, Kumar B. Effect of foliar spray of nano urea on yield and economics of rice. The Pharma Innovation Journal. 2023;12(1):3030-3033.

UNDER PEER REVIEW

Table 1 Effect of nano fertilizers and RDF levels on yield attributes of wheat crop (two year pooled)

| Treatments | No. of tillers/m ² | Length of spike (cm) | No. of spikes/m ² | No. of grains/spike | Test weight (g) |
|---|-------------------------------|----------------------|------------------------------|---------------------|-----------------|
| T ₁ 100% RDF + 2 FS nano N 35 & 55 DAS | 411 | 16.58 | 401 | 44.35 | 46.18 |
| T ₂ 100% RDF + FS nano P 35 DAS | 399 | 16.48 | 389 | 43.98 | 45.74 |
| T ₃ 100% RDF + ST nano P & 2 FS nano N 35 & 55 DAS | 431 | 17.03 | 414 | 45.24 | 46.32 |
| T ₄ 75% RDF + 2 FS nano N 35 & 55 DAS | 384 | 15.29 | 371 | 40.51 | 45.20 |
| T ₅ 75% RDF + FS of nano P at 35 DAS | 366 | 14.71 | 359 | 39.62 | 45.14 |
| T ₆ 75% RDF + ST nano P & 2 FS nano N 35 & 55 DAS | 396 | 15.88 | 382 | 41.94 | 45.40 |
| T ₇ 50% RDF + 2 FS nano N 35 & 55 DAS | 339 | 13.78 | 334 | 37.04 | 44.76 |
| T ₈ 50% RDF + FS nano P 35 DAS | 320 | 13.19 | 311 | 35.35 | 44.64 |
| T ₉ 50% RDF + ST nano P & 2 FS nano N 35 & 55 DAS | 348 | 14.24 | 339 | 37.66 | 44.81 |
| T ₁₀ FS nano P 35 DAS + 2 FS nano N 35 & 55 DAS | 263 | 10.68 | 252 | 29.83 | 43.13 |
| T ₁₁ ST nano P + FS nano P 35 DAS & 2 FS nano N | 277 | 11.09 | 273 | 31.58 | 43.20 |
| T ₁₂ ST nano P + 2 FS nano N 35 & 55 DAS | 226 | 9.23 | 220 | 25.58 | 42.83 |
| T ₁₃ 100% RDF conventional fertilizers | 390 | 15.33 | 374 | 40.67 | 45.22 |
| T ₁₄ Control | 159 | 7.29 | 154 | 17.77 | 40.70 |
| SEm± | 12.1 | 0.58 | 11.6 | 1.52 | 0.40 |
| CD (P=0.05) | 35.1 | 1.69 | 33.7 | 4.42 | 1.16 |

Comment [A9]: center aligned

Table 2 Effect of nano fertilizers and RDF levels on grain, straw, biological yield and harvest index of wheat crop (two year pooled)

| Treatments | | Grain yield (kg/ha) | | | Straw yield (kg/ha) | | | Biological yield (kg/ha) | | |
|-----------------|--|---------------------|---------|--------|---------------------|---------|--------|--------------------------|---------|--------|
| | | 2021-22 | 2022-23 | Pooled | 2021-22 | 2022-23 | Pooled | 2021-22 | 2022-23 | Pooled |
| T ₁ | 100% RDF + 2 FS nano N 35 & 55 DAS | 4099 | 4307 | 4203 | 5228 | 5502 | 5365 | 9327 | 9809 | 9568 |
| T ₂ | 100% RDF + FS nano P 35 DAS | 4027 | 4280 | 4154 | 5149 | 5473 | 5311 | 9177 | 9753 | 9465 |
| T ₃ | 100% RDF + ST nano P & 2 FS nano N 35 & 55 DAS | 4284 | 4513 | 4399 | 5351 | 5698 | 5525 | 9635 | 10212 | 9923 |
| T ₄ | 75% RDF + 2 FS nano N 35 & 55 DAS | 3793 | 4000 | 3896 | 4887 | 5206 | 5047 | 8680 | 9206 | 8943 |
| T ₅ | 75% RDF + FS of nano P at 35 DAS | 3645 | 3827 | 3736 | 4696 | 4983 | 4840 | 8341 | 8810 | 8575 |
| T ₆ | 75% RDF + ST nano P & 2 FS nano N 35 & 55 DAS | 3864 | 4066 | 3965 | 4949 | 5238 | 5094 | 8813 | 9305 | 9059 |
| T ₇ | 50% RDF + 2 FS nano N 35 & 55 DAS | 3400 | 3570 | 3485 | 4390 | 4714 | 4552 | 7790 | 8284 | 8037 |
| T ₈ | 50% RDF + FS nano P 35 DAS | 3229 | 3421 | 3325 | 4177 | 4452 | 4314 | 7405 | 7873 | 7639 |
| T ₉ | 50% RDF + ST nano P & 2 FS nano N 35 & 55 DAS | 3445 | 3640 | 3543 | 4432 | 4762 | 4597 | 7877 | 8402 | 8140 |
| T ₁₀ | FS nano P 35 DAS + 2 FS nano N 35 & 55 DAS | 2470 | 2854 | 2662 | 3227 | 3779 | 3503 | 5697 | 6633 | 6165 |
| T ₁₁ | ST nano P + FS nano P 35 DAS & 2 FS nano N | 2700 | 3045 | 2872 | 3530 | 3985 | 3757 | 6230 | 7029 | 6630 |
| T ₁₂ | ST nano P + 2 FS nano N 35 & 55 DAS | 2148 | 2440 | 2294 | 2838 | 3217 | 3027 | 4985 | 5657 | 5321 |
| T ₁₃ | 100% RDF conventional fertilizers | 3844 | 4030 | 3937 | 4941 | 5221 | 5081 | 8785 | 9250 | 9018 |
| T ₁₄ | Control | 1487 | 1720 | 1603 | 1980 | 2306 | 2143 | 3467 | 4026 | 3746 |
| SEm± | | 171.2 | 200.3 | 154.7 | 244.0 | 256.1 | 197.5 | 403.8 | 430.0 | 341.7 |
| CD (P=0.05) | | 497.8 | 582.2 | 449.7 | 709.2 | 744.4 | 574.1 | 1173.7 | 1249.9 | 993.4 |

Comment [A10]: center aligned