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Effect of Nano Fertilizers on Growth and Yield of Wheat (*Triticum aestivum* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

A field experiment was conducted at Instructional Farm, College of Agriculture, Jodhpur during two consecutive *rabi* seasons of 2021-22 and 2022-23. 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 DAP and two foliar sprays of nano urea at 35 and 55 days after sowing (DAS) was found the most effective treatment with recorded highest number of tillers (431/m^2), length of spike (17.03 cm), number of spikes (414 /m^2), 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 urea at 35 and 55 DAS, 100% RDF + FS of nano DAP at 35 DAS, 75% RDF + ST with nano DAP and 2 foliar spray of nano urea at 35 & 55 DAS but significantly superior over other treatments.

Keywords: Foliar spray; nano fertilizer; seed treatment; wheat; yield.

1. INTRODUCTION

Wheat (*Triticum aestivum* L.) is main staple food grain crop, It is consumed by nearly 36 per cent of the world population with more than half of their calories and nearly half of their protein but also core part of animal feed as straw in most of the countries [1]. 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 [2]. 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 [3]. 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 [4]. 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 [5]. The application of fertilizers in the crop fields is a common practice for increasing the crop production to fulfill the global demand of food [6]. The overuse of fertilizers in some regions and countries has led to worrying environmental problems such as the saturation of nutrients in soils and the loss of fertilizer via leaching to groundwater and via runoff to surface water leading to pollution of drinking water and eutrophication of freshwater rivers and lakes. However, conventional fertilizers don't provide the require 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 [7,8]**.** The alfisols of Western Rajasthan are deficient in nitrogen and phosphorus nutrients and farmers supply these nutrients in the form of fertilizers for normal growth and development of plants. Nitrogen is the important nutrient, its deficiency often limits crop production. It enhances vegetative growth and photosynthetic activity in wheat and increases the water use efficiency of wheat. 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 [9,10] Improvement of NUE is needed for better cropping systems, supporting the sustainable agricultural production systems and increasing soil quality components [11]. To address the challenges, innovative technologies with a potential of increasing the sustainability of the present-day cropping systems are required to be introduced in modern agriculture. Among these technological advancements, nanotechnology has the potential to contribute to a new technology-based agricultural revolution. Nano-materials differ from conventional materials having specific composition with unique property like small size of particle with high surface area, high reactivity and catalytic activity [12]. In precision agriculture, nano fertilizers offer a highly efficient means of precisely managing crop nutrients. These fertilizers can be administered at any stage of the crop's growth, aligning nutrient supply with the plant's specific developmental needs [13]. Foliar application of nutrients has been found to be more effective than soil application. This method enhances nutrient uptake by plants and reduces costs per unit area [14]. 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 [15]. 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. Recent research evidences indicated that intervention of nanotechnology in wheat farming is still in its early stages, although have bright prospects for efficient nutrient utilization through nano formulations of fertilizers, breaching yield barriers through bio nanotechnology, surveillance and management of pests and diseases and development of new-generation pesticides etc., so the present research work done on effect of nano fertilizers on growth and yieldof wheat (*Triticum aestivum* L.).

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^o 15' N to 26^o 45' North latitude and 73^o 00' E to latitude 73^o 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 inavailable 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 T_1-100% RDF + two foliar spray of nano urea at 35 & 55 DAS, T_2-100% RDF + foliar spray of nano DAP at 35 DAS, T_3-100% RDF + ST with nano DAP at 5 ml/kg seed and two foliar spray of nano urea at 35 & 55 DAS, T_4-75% RDF + two foliar spray of nano urea at 35 & 55 DAS, T_5-75% RDF + foliar spray of nano DAP at 35 DAS, T_6-100% RDF + ST with nano DAP at 5 ml/kg seed and two foliar spray of nano urea at 35 & 55 DAS, T_7-50% RDF + two foliar spray of nano urea at 35 & 55 DAS, T_8-50% RDF + foliar spray of nano DAP at 35 DAS, T_9-50% RDF + ST with nano DAP at 5 ml/kg seed and two foliar spray of nano urea at 35 & 55 DAS, T_{10}-Foliar spray of nano DAP at 35 DAS + two foliar spray of nano urea at 35 & 55 DAS, T_{11}-ST with nano DAP at 5 ml/kg seed + foliar spray of nano DAP at 35 DAS + two foliar spray of nano urea at 35 & 55 DAS, T_{12}- ST with nano DAP at 5 ml/kg seed + two foliar spray of nano urea at 35 & 55 DAS, T_{13}-100% RDF through conventional fertilizers and T_{14}-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 urea and DAP 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.

3. RESULTS AND DISCUSSION

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

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

Treatments		No. of tillers/m²	Length of spike (cm)	No. of spikes/m²	No. of grains/spike	Test weight (g)
T_1	100% RDF + 2 FS nano urea 35 & 55 DAS	411	16.58	401	44.35	46.18
T_2	100% RDF + FS nano DAP 35 DAS	399	16.48	389	43.98	45.74
T_3	100% RDF + ST nano DAP & 2 FS nano urea 35 & 55 DAS	431	17.03	414	45.24	46.32
T_4	75% RDF + 2 FS nano urea 35 & 55 DAS	384	15.29	371	40.51	45.20
T_5	75% RDF + FS of nano DAP at 35 DAS	366	14.71	359	39.62	45.14
T_6	75% RDF + ST nano DAP & 2 FS nano urea 35 & 55 DAS	396	15.88	382	41.94	45.40
T_7	50% RDF + 2 FS nano urea 35 & 55 DAS	339	13.78	334	37.04	44.76
T_8	50% RDF + FS nano DAP 35 DAS	320	13.19	311	35.35	44.64
T_9	50% RDF + ST nano DAP & 2 FS nano urea 35 & 55 DAS	348	14.24	339	37.66	44.81
T_{10}	FS nano DAP 35 DAS + 2 FS nano urea 35 & 55 DAS	263	10.68	252	29.83	43.13
T_{11}	ST nano DAP + FS nano DAP 35 DAS & 2 FS nano urea	277	11.09	273	31.58	43.20
T_{12}	ST nano DAP + 2 FS nano urea 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**

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 urea 35 & 55 DAS	4099	4307	4203	5228	5502	5365	9327	9809	9568
T_2	100% RDF + FS nano DAP 35 DAS	4027	4280	4154	5149	5473	5311	9177	9753	9465
T_3	100% RDF + ST nano DAP & 2 FS nano urea 35 & 55 DAS	4284	4513	4399	5351	5698	5525	9635	10212	9923
T_4	75% RDF + 2 FS nano urea 35 & 55 DAS	3793	4000	3896	4887	5206	5047	8680	9206	8943
T_5	75% RDF + FS of nano DAP at 35 DAS	3645	3827	3736	4696	4983	4840	8341	8810	8575
T_6	75% RDF + ST nano DAP & 2 FS nano urea 35 & 55 DAS	3864	4066	3965	4949	5238	5094	8813	9305	9059
T_7	50% RDF + 2 FS nano urea 35 & 55 DAS	3400	3570	3485	4390	4714	4552	7790	8284	8037
T_8	50% RDF + FS nano DAP 35 DAS	3229	3421	3325	4177	4452	4314	7405	7873	7639
T_9	50% RDF + ST nano DAP & 2 FS nano urea 35 & 55 DAS	3445	3640	3543	4432	4762	4597	7877	8402	8140
T_{10}	FS nano DAP 35 DAS + 2 FS nano urea 35 & 55 DAS	2470	2854	2662	3227	3779	3503	5697	6633	6165
T_{11}	ST nano DAP + FS nano DAP 35 DAS & 2 FS nano urea	2700	3045	2872	3530	3985	3757	6230	7029	6630
T_{12}	ST nano DAP + 2 FS nano urea 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**

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 ureaitrogen 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 [16-19]. Results (Table 2) indicated that 100% RDF + ST with nano DAP and 2 FS of nano urea 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 urea at 35 and 55 DAS, 100% RDF + FS of nano DAP at 35 DAS and 75% RDF + ST with nano DAP and 2 FS of nano urea at 35 & 55 DAS but remained significantly superior over treatments applied with 50% RDF in combination with nano fertilizers. Application of ST with nano DAP + 2 FS of nano urea 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 DAP and 2 FS of nano urea at 35 & 55 DAS significantly improved the grain yield by 881 and 1940 kg/ha over FS of nano DAP at 35 DAS + 2 FS of nano urea 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*.* [20] 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 DAP exhibited slow-release characteristic throughout the growth period, which consequently elevated chlorophyl synthesis and leads to a substantial accumulation of biomass yield. Liu and Lal's [21] 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 [21]. Indeed, recent studies by Velmurugan et al*,* [22] and Sahu et al*.* [20] have demonstrated that nano fertilizers performed better than commercial urea in different crops [20,22]. Ahmadian et al*.,* [23] also reported that nano fertilizers significantly boosts wheat grain yield by improving various growth parameters such as plant height, spike length, number of grains per spike, 1000-grain weight, and overall biological yield.These findings are in close conformity with the results reported by [19,24-27].

4. 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 P_2O_5 and 20 kg K_2O/ha) along with seed treatment with nano DAP @ 5 ml/kg of seed and two foliar spray of nano urea at 4 ml/L of water at 35 & 55 DAS for higher production.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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