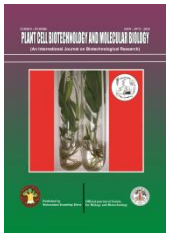

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Impact of Nano-fertilizers on Productivity and Profitability of Wheat (*Triticum aestivum* L.)

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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

Yield stagnation, multi-nutrient deficiencies coupled with reduced fertilizer-use efficiency have emerged as major challenges to the food-systems of South Asia. Modern scientific tools to enhance nutrient use efficiencies along with augmented crop yields became utmost necessity to sustain food security of developing world. In this context, a field study was undertaken to understand the influence of numerous nano-fertilizers on wheat productivity, profitability and nutrient-use efficiency. Results revealed that application of 100% NPK coupled with foliar-spray of Nano- N + P + K + Zn increased grain and straw yield by 29.8 % and 13.7 %, respectively over 100% NPK. The crop fetched a net return of ₹ 72141.50 with B:C ratio of 5.51 with 75% NPK + nano-N. As a result, the wheat crop produced when Nano-N + 75% NPK was applied produced a greater yield (grain, straw, and biological), as well as financial gains.

Keywords: Bio-nano k; bio-nano p; bio-nano zn; nano n; wheat.

1. INTRODUCTION

Wheat is the most important crop for human consumption and the most widely produced cereal in the world. Wheat is grown on an area of 216.9 million ha, and it leads to a total yield of 734.03 million metric tonnes of grain. The average productivity of wheat is 3.39 tonnes per hectare (USDA report, 2018-19). The crop alone supplies 20% of the protein and 21% of the food calories for the 4.5 billion people globally. In India, wheat contributes to around one-third of all food grain output (Tandon, 2000), and is kingpin of the food and nutritional security of the nation. India had witnessed multi-fold productivity enhancement, particularly wheat yields, during the green revolution period of the 1970's leading to food sufficiency in this ecologically and demographically fragile part of the world [1].

It is widely documented that the productivity improvements were attributable to the development of high yielding dwarf and fertilizer-responsive cultivars of cereals, primarily wheat and rice. According to estimates, fertiliser inputs contribute between 30 and 40% to crop production [2]. However constant use of traditional blanket fertiliser suggestions and an over reliance on high-analysis fertiliser have resulted in widespread macro- and micronutrient shortages, particularly in phosphorus, potassium, and zinc [3]. Nitrogen, phosphorus, and potassium application ratios in the rice-wheat (15:06:01), sugarcane-ratoon-wheat (10:04:01), rice-wheat-gram (13:06:01), and maize-wheat (34:17:01) cropping systems were very different from what they should have been (Singh, 2014). Unfortunately, in addition to a declining crop yield ratio and approximately 8–10 million tonnes of NPK extraction in India exclusively, this has had a severe impact on soil health and human well-being [4].

Nanoparticles seem to be very minute, with at least one diameter being below 100 nm (dimensions on the size scale are 10-9). They have the ability to change the agricultural and food sectors by improving plants' capacity to absorb nutrients, curing illnesses at the molecular level, quickly identifying ailments, etc [5]. Higher fertiliser use efficiency is achieved by these nanoparticles' vast surface area, which allows them to hold onto a lot of nutrient ions and release them gradually and consistently in response to crop demands [6]. The revolutionary nutritional agricultural inputs, which include Nano/Bio-Nano NPK and Zn solution are eco-sustainable fertilisers' formulations with organic and chelated micronutrients, are known to maintain soil fertility and secure high yield without affecting the environment [7].

2. MATERIALS AND METHODS

2.1 Research Site

The experiment was done at the agricultural research centre of the SVPUA&T, Modipuram, Meerut situated in the Indo-Gangetic plains of north India. The crop's mean weekly lowest temperature ranged from 7.6 ^{0}C in the second week of January to 36.3^{0}C in the fourth week of April in 2020. The wettest week of the year was the first week of March (95.3%), although the second week of April saw the driest crops (22.0%). Hence, the evaporation requirement of the atmosphere reached its peak (86.50 mm) during the final week of April and its lowest (1.3 mm) during the first week of January. 190 mm of rain fell on the crop during that time.

2.2 The Soil of the Experiment Field

A composite soil sample was randomly selected samples from 15 cm of soil depth before initiating the experiment to analyse various soil properties. Based on the analysis of fourteen samples, the texture (hydrometer method) at the site was found to be sandy with 47.8 %, silt18.6 %, and 32.6% clay on the field (2019-20). The field had a soil pH of 8.2 (Glass electrode pH meter), EC 0.22 dsm^{-1} at $25C^{o}$ (Solubridge), organic matter (Walkley-Black) of 0.45%, Available Nitrogen 210.0 kg per hectare (Alkaline potassium permanganate method) and Available phosphorus of 12.5 kg per hectare (Extraction by 0.5 M $nahco_3$ Solution at pH 8.5, Olsen's method), available potassium of 244.0 kg per hectare (Extraction with Neutral 1 N ammonium acetate and estimated by flame photometer), available Zinc of 0.81 ppm [8].

2.3 Experimental Details

The experiment was designed was a randomised block design and three replication with fourteen treatments comprising levels of NPK (100% and 75%) in combination with nano/bio nano fertilizer (NPK and Zn).

2.4 Agronomic Management

Di-Ammonium Phosphate (DAP), Muriate of potash (MOP), and 50% of the nitrogen were all treated in full at the time of sowing, and the remaining nitrogen was top-dressed in two equally spaced applications at the CRI and tillering periods. By combining in 500 litres of water per hectare, nano nitrogen (4 ml per litre), bio-nano phosphorus (40 ml per litre), bio-nano potash (40 ml per litre), and bio-nano zinc (40 ml per litre) were applied. According to the treatments, the sprays were applied at 28 and 45 days following seeding and were applied all at once.

2.5 Observations

The data on Effective tillers per m^2, ear length (cm), spikelets per spike, grains per spike, test weight, grain yield, straw yield, biological yield, harvest index and cost of cultivation were collected and analyzed.. According to Gomez and Gomez (1984), the impact of various treatments on yield and economics of Wheat was statistically compared (P=0.05) using a one-way ANOVA (analysis of variance) for randomised full block design.

3. RESULTS AND DISCUSSION

3.1 Yield Attribute

Crops fertilized with various nutrients, their levels and sources, had significantly higher effective tillers than control (Table. 1). Application of Nano-nutrients in addition to 100% NPK related to an increase of 12.7, 8.6, 7.5, 10.1, and 14.6% with Nano- N, P, K, Zn and N + P + K + Zn over 100% of NPK. Repetitive increase with 75% of NPK was 10.8, 7.5, 6.7, 8.6 and 13.1% over 100% NPK.

Application of Nano-nutrients in addition to 100% NPK resulted in an increase of 26.0, 15.3, 21.4 and 40.5% with Nano-N, P, K, Zn and N + P + K + Zn over 100% of NPK. Respective increase with 75% of NPK was 22.9, 12.2, 8.4, 14.5 and 32% over 100% NPK. Alike other yield attributes, grains per spike also increased significantly with the application of nutrients irrespective of the dose and sources, and it ranged from 36.5 with no nutrient application to 47.8 with 100% NPK + nano N + P + K + Zn.

Crop receiving 75% NPK with Nano N +Bio Nano P, Bio Nano K + Bio Nano Zn gave higher 29.3 and 11.1 % grains per spike than control and 100% of NPK, but remained at par with all other treatments involving nano nutrients and NPK (100 or 75%). Non-significant variation was observed in test weight (g) under different nutrient management practices. Test weight ranged from 35.4 g with no nutrient application to 40.3 g with 100 % NPK + Nano N + Bio Nano P + Bio Nano K + Bio Nano Zn spray (Table - 1). The crop receiving 75% NPK with Nano N + Bio Nano P + Bio Nano K + Bio Nano Zn recorded the highest test weight followed by 100 % NPK along with nano nutrients and proved better than 100% NPK. According to Benzon et al. (2015), Improved nutrient uptake by plant cells, optimum development of plant parts, and the transfer of photosynthetic activity to the plant's productive parts are all outcomes of the synergistic effects of nano-fertilizers on the effectiveness of traditional fertilisers. Manjunath et al. [5] found high yields due to higher source (leaves) and sink (economic component) strength. According to Tarafdar et al. (2013) foliar use of nano-fertilizers dramatically improves crop yields.

Table 1. Effect of nano-nutrients on yield attributes

Treatments	Yield attributes				
	Effective tillers per m^2	Ear length (cm)	Spikelets per spike	Grains per spike	Test weight (g)
Control	222	7.2	10.2	36.5	35.4
NPK (150:60:40)	268	8.0	13.1	42.5	36.4
100 %NPK + water spray at 28 and 45 DAS	269	8.2	13.4	42.9	36.7
100 % NPK + Nano N spray at 28 and 45 DAS	302	10.8	16.5	46.6	38.8
100 % NPK + Bio Nano P spray at 28 and 45 DAS	291	9.0	15.1	44.5	38.1
100 % NPK + Bio Nano K spray at 28 and 45 DAS	288	8.6	14.5	43.6	37.2
100 % NPK + Bio Nano Zn spray at 28 and 45 DAS	295	9.8	15.9	45.7	38.4
100 % NPK + Nano N + Bio Nano P + Bio Nano K + Bio Nano Zn spray at 28 and 45 DAS	307	12.4	18.4	47.8	40.3
75 % NPK + water spray at 28 and 45 DAS	260	7.4	11.2	38.4	35.8
75 % NPK + Nano N spray at 28 and 45 DAS	297	10.2	16.1	46.2	38.4
75 % NPK + Bio Nano spray P at 28 and 45 DAS	288	8.6	14.7	44.2	37.6
75 % NPK + Bio Nano spray K at 28 and 45 DAS	286	8.4	14.2	43.1	36.8
75 % NPK + Bio Nano Zn spray at 28 and 45 DAS	291	9.1	15.0	44.8	38.2
75 % NPK + Nano N + Bio Nano P + Bio Nano K + Bio Nano Zn spray at 28 and 45 DAS	303	11.3	17.3	47.2	39.4
SEm±	7.9	0.3	0.4	1.3	1.1
CD (P = 0.05)	23.0	0.8	1.2	3.8	N/S

3.2 Yield

As indicated by the data given in Table 2, fertiliser application, irrespective of nutrients, increased grain yield significantly over no nutrient application. Over 100% NPK, spraying Nano N, P, K, Zn, and nano-N + P+ + K+ Zn with 100% NPK increased grain yield by 0.89 tonnes per hectare(21.5%), 0.69 tonnes per hectare(16.7%), 0.66 tonnes per hectare(16.0%), 0.79 tonnes per hectare(19.1%), and 0.123 tonnes per hectare(29.8%).Respective increase with 75% of NPK with spray of Nano N, P, K, Zn and N + P+ +K+ Zn was 0.74 tonnes per hectare (17.90 %), 0.65 tonnes per hectare (15.7%), 6 tonnes per hectare (14.5%), 0.68 tonnes per hectare (16.5%) and 0.11 tonnes per hectare (26.9%).

Application of 100% NPK added with a spray of nano-fertilizer - N, P, K, Zn and N + P+ +K+ Zn increased straw yield by 0.53 t per hectare(8.8%), 0.43 t per hectare(7.1%), 3.5 q per hectare (5.8%), 0.50 q per hectare(8.3%) and 0.83 q per hectare (13.7%) over 100% NPK. Respective increase with 75% of NPK was 0.42 t per hectare (7.0%), 0.36 tonnes per hectare (6.0%), 0.5 tonnes per hectare (5.0%), 0.4 tonnes per hectare (6.6%) and 0.59 tonnes per hectare (9.8%). Crop fertilized with 75% NPK + nano N + P + K + Zn gave higher straw yield 0.24 & 0.6 q per hectare than control and 100% NPK. Similarly, Application of 100% NPK added with spray of nano nutrient- N, P, K, Zn and N + P+ +K+ Zn increased biological yield by 0.13 tonnes per hectare (13.2%), 0.10 tonnes per hectare (10.1%), 0.96 tonnes per hectare (9.3%), 0.9 tonnes per hectare (8.5%) and 1.9 tonnes per

hectare (19.1%) over 100% NPK. Respective increase with 75% of NPK was 1.1 tonnes per hectare (10.7%), 0.91 tonnes per hectare (8.9%), 0.84 tonnes per hectare (8.2%), 1.06 tonnes per hectare (10.3%) and 1.6 tonnes per hectare (15.9%).

A crop fertilised with 75% NPK + nano N + P + K + Zn gave a higher yield of 11.9 & 1.6 tonnes per hectare than control and 100% NPK. The harvest index varied from 38.8% with no nutrient application to 44.4% with application of 100% NPK with nano- N, P, K, and Zn. A crop fertilized with 100% NPK with nano P + K + Zn recorded the highest harvest index (44.4%) followed by 100% NPK with Bio Nano Zn.The researchers attribute these results to the synergistic effects of inorganic and nano fertilizers. Inorganic and nano fertilizers work together to enhance the solubility and diffusion of minerals in the soil, prevent fixation of nutrients, and increase their bioavailability. This leads to improved nutrient uptake, increased fertilizer efficiency (specifically for NPK), and ultimately higher crop yields. The authors of the statement mention that their findings are consistent with previous studies conducted by AL-Gym et al. [9], Abdel et al. [10], Rawat et al. [11], and Kandil et al. [12], which support the positive effects of combining inorganic and nano fertilizers on crop productivity.

3.3 Economic

The information in Table 3 shows that the cost of cultivation varies, ranging from ₹ 40866 per hectare for crops cultivated without fertiliser treatment to ₹ 135689.5 per hectare for crops receive with 100% NPK + Nano N + Bio nano P, K & Zn. Gross revenues ranged from ₹ 66875 per ha for a crop grown without any of the application of nutrients to the maximum of ₹ 12980 per hectare for a crop raised with 100% NPK + Nano N + Bio nano P, K, and Zn.

Table 2. Effect of nano-nutrients on yield

Treatments	Yield (t per hectare)			
	Grain	**Straw**	**Biological**	**Harvest index**
Control	2.72	4.17	7.01	38.8
NPK (150:60:40)	4.13	6.04	10.28	39.6
100 %NPK + water spray at 28 and 45 DAS	4.17	6.09	10.34	39.6
100 % NPK + Nano N spray at 28 and 45 DAS	5.02	6.57	11.64	43.1
100 % NPK + Bio Nano P spray at 28 and 45 DAS	4.82	6.47	11.32	42.2
100 % NPK + Bio Nano K spray at 28 and 45 DAS	4.79	6.39	11.24	42.1
100 % NPK + Bio Nano Zn spray at 28 and 45 DAS	4.92	6.54	11.15	44.1
100 % NPK + Nano N + Bio Nano P + Bio Nano K + Bio Nano Zn spray at 28 and 45 DAS	5.36	6.87	12.24	44.4
75 % NPK + water spray at 28 and 45 DAS	3.91	5.84	10.18	38.4
75 % NPK + Nano N spray at 28 and 45 DAS	4.97	6.46	11.38	42.8
75 % NPK + Bio Nano spray P at 28 and 45 DAS	4.78	6.4	11.19	42.2
75 % NPK + Bio Nano spray K at 28 and 45 DAS	4.73	6.34	11.12	41.9
75 % NPK + Bio Nano Zn spray at 28 and 45 DAS	4.81	6.44	11.34	42.8
75 % NPK + Nano N + Bio Nano P + Bio Nano K + Bio Nano Zn spray at 28 and 45 DAS	5.24	6.63	11.91	44.0
SEm±	**1.8**	**2.3**	**4.2**	**1.6**
CD (P = 0.05)	**5.2**	**6.6**	**12.3**	**N/S**

Table 3. Effect of nano-nutrients management on Cost of cultivation, Gross return, Net return and B: C ratio in wheat

Treatments	Cost of cultivation (Rs per hectare)	Gross return (Rs per hectare)	Net return (Rs per hectare)	B: C ratio
Control	40866	65960	25094.00	1.61
NPK (150:60:40)	50489.5	100152.5	49663.00	1.98
100 %NPK + water spray at 28 and 45 DAS	51369.5	101122.5	49753.00	1.97
100 % NPK + Nano N spray at 28 and 45 DAS	51289.5	121735	70445.50	2.37
100 % NPK + Bio Nano P spray at 28 and 45 DAS	85769.5	116885	31115.50	1.36
100 % NPK + Bio Nano K spray at 28 and 45 DAS	85769.5	116157.5	30388.00	1.35
100 % NPK + Bio Nano Zn spray at 28 and 45 DAS	56969.5	119310	62340.50	2.09
100 % NPK + Nano N + Bio Nano P + Bio Nano K + Bio Nano Zn spray at 28 and 45 DAS	135689.5	129980	-5709.50	0.96
75 % NPK + water spray at 28 and 45 DAS	49961.5	94817.5	44856.00	1.90
75 % NPK + Nano N spray at 28 and 45 DAS	47881.5	120023	72141.50	2.51
75 % NPK + Bio Nano spray P at 28 and 45 DAS	84361.5	115915	31553.50	1.37
75 % NPK + Bio Nano spray K at 28 and 45 DAS	84361.5	114702.5	30341.00	1.36
75 % NPK + Bio Nano Zn spray at 28 and 45 DAS	55561.5	116642.5	61081.00	2.10
75 % NPK + Nano N + Bio Nano P + Bio Nano K + Bio Nano Zn spray at 28 and 45 DAS	134281.5	127070	-7211.50	0.95

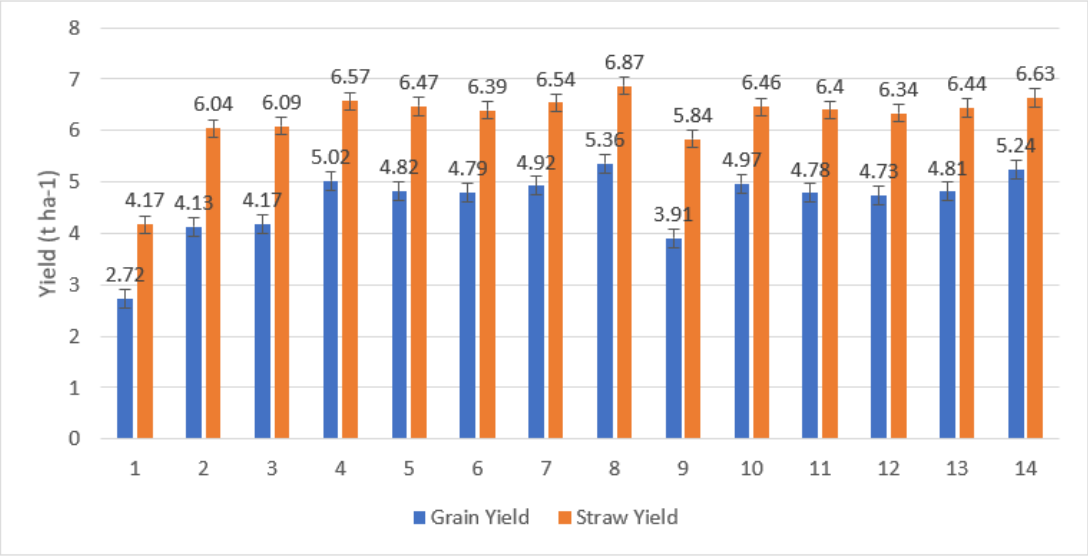

Fig. 1. Impact of nano-fertilizer on yield (Grain and Straw)

The crop produced with 75% NPK + Nano N fetched the greatest net returns of ₹ 72141.5 per hectare, preceded by 100% NPK + Nano N ₹ 70445.50 per ha. A crop receiving 75 % NPK along with Nano N gave a net return higher by ₹47047 per hectare than control and ₹22478 per hectare than 100% NPK. The benefit-cost ratio was highest (5.51) in the crop grown with 75% NPK + Nano N and lowest (0.95) in the crop grown with 75% NPK + Nano N + Bio Nano P, K

& Zn. Sarkar et al. [13-16] found that the cost of wheat farming varied depending on the nutrient management techniques used [17-20].

4. CONCLUSION

With the aforementioned information, it is no longer an obscure that nutrient management techniques significantly and profoundly impacted wheat production characteristics, yield, and returns. Application of nano-nutrients, N, P, K, and Zn individually and simultaneously promoted growth of the crop and enhanced grain yield significantly. Additionally, nano/bio nano sources (N, P, K, and Zn) have the potential to promote growth and yield formation in wheat. The wheat crop produced with 75% NPK + nano N + bio nano P + bio nano K + bio nano Zn spray at 30 and 45 DAS resulted in significantly better productivity than 100% NPK and control, but remained at par with that receiving 100% NPK along with nano-nutrients. However, the net returns were highest (₹ 87141 per hectare) when 75% NPK + nano-N were used, being higher by 18478 per hectare than 100% NPK (₹ 68663 per hectare).

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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