



Evaluation of the Potential of Smart Fertilizers on Growth and Nutrient Availability 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 crop research centre of SVPUA&T, Meerut (U.P.) India during 2020-21. Novel nutrient sources and their modes of applications with 12 treatments consisting of Control, NPK-(150:60:40 q ha⁻¹), 100 % NPK + Nano Zn spray, 100 % NPK + Bio-stimulant spray, 75 % NPK + NPK Consortia, 75 % NPK + NPK spray, 75 % NPK + NPK Consortia + Nano N spray, 75 % NPK + NPK Consortia + NPK spray, 75 % NPK + NPK Consortia + NPK spray + Bio-stimulant spray, 75 % NPK + NPK Consortia + NPK spray + Bio-stimulant spray + Nano Zn spray, 75 % NPK + NPK Consortia + Nano Zn spray, 75 % NPK + NPK Consortia + Nano N spray + Nano Zn spray were attempted on wheat variety HD 2967 in randomized complete block design (RCBD) with three replications. The application of 75 % NPK + NPK Consortia + NPK spray + Bio-stimulant spray + Nano Zn spray was found at par with 100 % NPK nano Zn / Bio-stimulant and significant over recommended dose of fertilizer (RDF) with a better growth attribute and yield *ie.* plant population (307.8 no. m⁻²), plant height (110.6 cm), number of tillers m⁻¹ row length (68.9), dry matter accumulation (294.0 g m⁻¹) and grain yield (55.9 q ha⁻¹) with a better availability of nutrients in soil.

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1. INTRODUCTION

Wheat (*Triticum aestivum* L.) is the world's most important staple crops, providing 21% of calories and 20% of protein to 4.5 billion people. World wheat acreage is 216.18 million ha, generating 763.6 million metric tonnes at 3,530 kg ha⁻¹ [1]. In India, it occupies 29.32 million hectares and produces 103.6 million metric tonnes annually-equal to one-third of the country's total food grain output with a productivity rate of 3,530 kg ha⁻¹ per year [1].

It is projected that by the year 2050, the current global population of 7.7 billion would have increased to 9.7 billion. India now has a population of 1.3 billion people, making it the world's second-most populous nation behind China's 1.41 billion people. However, it is projected to overtake China's population and reach a peak of 1.7 billion by the year 2050. (The UN World Population Prospects: The 2019 Revision). As a consequence of this, it is expected that wheat will continue to play an important role in guaranteeing the food security of the entire world. To meet this increasing demand at the national level, farmers use more and more chemical fertilizers to enhance crop production. Excessive use of chemical fertilizers adversely affects the soil physicochemical and microbial properties which consequently decline productivity. Nowadays it is important to grow a crop with higher yields by maintaining soil fertility for the future generations. Fertilizers, such as urea, diammonium phosphate (DAP), and muriate of potash (MOP), play a vital role in optimizing crop yield, farmers in general use a high dose of chemical fertilizers during wheat cultivation in order to harvest high grain yields because of this degradation of soil is also increasing. According to [2] extensive use of chemical fertilizers has a variety of negative effects on the environment, some of which are the erosion of soil fertility, the reduction of organic matter absorption, the lessening of water holding capacity, and the mobilization and uptake of nutrients by root systems. As indicated by Subramanian et al. [3] the efficiency of nutrients usage for nitrogen, phosphorus, and potassium still stands at 30 to 35 %, 18 to 20 %, and 35 to 40 % respectively. Low fertilizers use efficiency not only drives up the cost of production but also creates a number of serious problems for the surrounding ecosystem. In addition, the rather volatile global market has led to an increase in the price of fertilizers. In light of all these points, it

is necessary for us to develop a procedure for the management of fertilizers that is focused on efficiency. Because there is a shortage of arable land, as well as limited water and fertilizers supplies, it is necessary to maximize the efficiency with which resources are used without sacrificing productivity by making good use of modern technologies [4]. The application of nanotechnology in this setting aims to maximize the effectiveness of fertilizers application. Many different nano-sized fertilizers as well as smart delivery-based fertilizers that have a surface coating of nanoparticles have garnered the attention that they deserve over the course of the past few years. Nano-bio minerals are a concept to formulate nano-scale rock minerals embedded with biological-based nano-structures, which are having self-assembling properties. The size of these materials ranges from 100-1000 nm size. These materials can be easily taken up by root hairs and can enter in plant system rapidly, because they are easily suspended in soil solutions, and create a higher nutrient concentration near the root surface. According to Narang et al. [5] foliar application of nutrients is superior to soil application since it results in higher plant utilization and cheaper costs per unit area. In addition, an increased rate of photosynthetic activity as well as an improved transport of these nutrients from the leaves to the grains that are forming. Biofertilizers are a method of increasing output that is not only inexpensive but also capital-intensive, non-bulk, and good to the environment [6]. The use of bio-stimulants as a fertilizer is of utmost significance if biochemical fertilizers are to be substituted for commercially available chemical fertilizers. Seaweed Extract is a natural organic fertilizer that is extremely effective, of the latest generation, and stimulates growth and yield in addition to enhancing a variety of crops' resilience to stress from both biotic and abiotic agents [7]. In contrast to chemical fertilizers, extracts obtained from seaweed are not only inexpensive to produce but also biodegradable, safe for the human, animal, and avian consumption, and they do not contribute to environmental pollution [8]. Excessive use of chemical fertilizers adversely affected the environment and soil health. Therefore, balanced and integrated application of nano nutrients, bio-fertilizers, bio-stimulants and inorganic fertilizers should be a key factor in order to achieve improved and sustainable soil fertility and crop yield.

2. MATERIALS AND METHODS

The experiment was conducted at the crop research centre of the University located in the Indo-Gangetic plains of Western Uttar Pradesh. At 29° 5' 34" N latitude, 77° 41' 58" E longitudes and at an elevation of 230 meters above the mean sea level. Meerut lies 65 km away from Delhi on the national highway 58 linking New Delhi and Dehradun. The field was having well drained sandy clay loam soil, low in organic carbon and available nitrogen, medium in available phosphorus, potassium and zinc and moderately alkaline in pH. The mean weekly minimum temperature for crop in 2021 ranged from a low of 4.90 °C in the fourth week of December to a high of 38.20 °C in the second week of April. The second week of January had the most humidity at 94.9 %, but the second week of April was the month with the lowest rainfall at 22.0 % during the agricultural season. During its growing season, crop was blessed with 39.9 millimeters of rainfall. The wheat crop was sown with a spacing of 22.5 cm with a seed rate of 100 kg ha⁻¹. Nutrient doses used were recommended dose of NPK (kg ha⁻¹): 150:60:40, NPK-(18:18:18): 15 g litre⁻¹, bio-stimulant: 625 ml ha⁻¹, NPK consortia seed treatment: 250 ml in 3 litre water 60 kg⁻¹ seed, dose of nano material: nano N-@ 4 ml litre⁻¹, nano Zn-@ 10 ml litre⁻¹, where spray were done @ 500 l ha⁻¹ water. As to find out the effect of treatments on the growth of crop, observations on plant population, plant height, number of tillers and dry matter accumulation were recorded at harvest as under: The number of plants at three marked places each 0.20 m in length from each plot were recorded at harvest and expressed as a number per m². Five plants were tagged randomly in the sampling area for recording the height. The height was measured in centimeters from the ground surface to the tip of fully expanded leaves. The height of all the five plants were summed and averaged to express plant height in centimeters. The number of tillers were recorded on 3 marked places each 0.20 m length in each plot, averaged and expressed as number m⁻¹ row length. Row length, measuring 0.20 m, was measured at three places randomly and all the plants falling in the row were cut close to the ground and sun-dried. The sun-dried matter was kept in the oven at 70±2 °C temperature till the constant weight was achieved. The oven-dried weight was recorded, averaged and expressed as dry matter accumulation in gram per metre row length (g m⁻¹). The grains obtained after threshing and winnowing of each of the net - plot

was weighed in kilograms. The grain yield was further converted on a hectare basis and expressed quintals. Available Nitrogen was estimated by the alkaline potassium permanganate (KMnO₄) method as per the standard procedure given by Subbiah and Asija, [9]. The available phosphorus content of the soil was determined by the method as described by Olsen et al. [10]. The available potassium content of the soil was determined as described by Hanway and Heidel, [11]. Available Zn in the soil was extracted by DTPA and Zn, in the extract was determined by Atomic Absorption Spectrophotometer as documented by Lindsay and Norvell, [12]. The Organic carbon content of the soil sample was determined by Walkely and Black, [13] wet oxidation method. Statistical analysis was done with the help of window-based SPSS (Statistical Product and Service Solutions) Version 10.0, SPSS, Chicago, IL. The SPSS technique was used for the analysis of variance to define the statistical significance of the treatment effect at a 5 % probability level. Further, F- test and the significance of the difference between the treatments were examined by critical difference (CD) as described by Gomez and Gomez, [14].

3. RESULTS AND DISCUSSION

Wheat, being an intensive tillering crop, plant population increased manifold at a later stages (harvest) where it exhibited significant variations. Crop fertilized with 100 % NPK + Nano Zn spray was having the highest plant population at the harvest stage being significantly superior over control, 75 % NPK + NPK Consortia, 75 % NPK + NPK spray and RDF but remained at par with other nutrient management practices (Table 1). Substituting 25% NPK with NPK Consortia + NPK spray + Bio-stimulant spray + Nano Zn spray proved significantly superior over Control, RDF, 75 % NPK + NPK Consortia and 75 % NPK + NPK spray and remained at par with the rest of the treatments. This may be due to increased nutrient use efficiency which resulted in profuse tillering with a better plant stand. A similar result was reported by Al-Juthery et al. [15]. At a later stage *ie.* at harvest, the application of either Nano fertilizers, Bio-fertilizer, Bio-stimulant, and Inorganic fertilizers spray or their simultaneous use with 100% or 75% NPK increased plant height remarkably over 100% NPK except 75% NPK + NPK Consortia and 75 % NPK + NPK spray. Crop fertilized with 100 % NPK + Nano Zn spray registered taller plants at all the stages (except 30 DAS *ie.* at this date no spray were

done) being significantly superior over control, 100 % NPK, 75 % NPK + NPK Consortia, 75 % NPK + NPK spray, 75 % NPK + NPK Consortia + Nano N spray and rest of the treatments were at par. A similar, an increase in plant height with application of NPK with nano-nutrient (NPK) by Mehta S. [16], with nano-Zn by Rizwan et al. [17] has also been reported. Further at the harvest, application of either nano fertilizers, bio-stimulant, and inorganic fertilizers spray or their simultaneous use with 100%/75% NPK and NPK Consortia or without NPK-Consortia increased number of tiller m^{-1} over 100% NPK except the treatment having 75 % NPK + NPK Consortia and 75 % NPK + NPK spray. Crop fertilized with 100 % NPK + Nano Zn spray had the highest number of tillers at all the stages (except 30 DAS *ie.* no spray were done before it) being significantly superior over control, 75 % NPK + NPK Consortia and 75 % NPK + NPK spray but remained at par with those receiving any combination with 75 and 100% NPK with all other nano fertilizers, biofertilizer, bio-stimulant, and inorganic fertilizers spray inputs (Nano N + Nano Zn+ NPK-Consortia + Bio-stimulant + NPK spray). The profuse tillering was due to the fact that nano fertilizers enhanced emergence, more efficient nutrient utilization satisfying nutrient requirement of crop and increased activity of chloroplast [18], bio-fertilizers [19]. Similarly, at the harvest application of either nano fertilizers, bio-stimulant, and inorganic fertilizers spray or their simultaneous use with 100%/75% NPK with or without NPK-Consortia increased plant dry matter significantly over control. The application of 100 % NPK + Nano Zn spray resulted in maximum accumulation of dry matter at all growth stages in compare to 100%/75% RDF with nano fertilizers, biofertilizer, bio-stimulant, and inorganic fertilizers spray and control. The application of either nano fertilizers or bio-stimulant, in addition to 100% NPK resulted in an increase in dry matter accumulation over of 75 % NPK at the harvest with any combination of nutrients. Enhanced fertilizers doses coupled with a greater concentration of bio-stimulant increased the nutrient supplying capacity to the wheat plants which in turn resulted in a higher growth rate. A similar results were given by Khan et al. [19, 20]. According to data in (Table 1), fertiliser application considerably boosted grain production over no fertiliser application, regardless of nutrients levels and sources. When 100 % NPK was applied along with a spray of Nano Zn and Bio-stimulant, grain yield increased by 7.6 q ha^{-1} (15.5%) and 6.7 q ha^{-1} (13.6%) over 100 % NPK. The application of NPK- Consortia +

NPK + Bio-stimulant + Zn spray with 75% NPK resulted in an increase in grain production of 6.8 q ha^{-1} (13.8%) above 100% NPK alone. In the treatment, omission of Nano Zn and substitution of NPK spray with Nano N + omission of Bio-stimulant narrowed down the increase to 4.4 q ha^{-1} (8.9%) and 5.7 q ha^{-1} (11.6%) respectively. The use of growth-stimulating seed inoculants helps to accelerate the uptake of plant nutrients from applied fertilizers by increasing the root growth which increased overall yield [21]. A perusal of data given in (Table 2) indicated that the plot receiving 100 % NPK + Bio-stimulant spray had the highest available nitrogen (211.8 kg ha^{-1}) after crop harvest closely followed by 75 % NPK + NPK Consortia + Nano Zn spray whereas, the lowest (174.5 kg ha^{-1}) was recorded in the control plot. Further data indicated that the available phosphorus in soil ranged from 10.8 kg ha^{-1} under control to 15.2 kg ha^{-1} in plots receiving 100 % NPK + Bio-stimulant spray when tested along with all the Nano fertilizers, Biofertilizers, Bio-stimulant, and Inorganic fertilizers spray. Similarly data shows that available soil potassium, at the crop harvest, varied in the range of 132.7 to 154.8 kg ha^{-1} being the lowest in the control plot and highest in 100% NPK. Further, soil available zinc ranged in a narrow range from 0.79 to 0.87 mg kg^{-1} , the lowest in the control plots and higher in plots applied with 75 % NPK + NPK Consortia + Nano Zn spray. Residual zinc content was lower in the treatment with 75% NPK in comparison to there being 100% NPK, though the differences were not significant. Further soil organic carbon did differ significantly by the nutrient management practices. The highest soil organic carbon (0.49%) was recorded in the plot having an application of 75 % NPK + NPK Consortia + NPK spray + Bio-stimulant spray + Nano Zn spray. The lowest organic carbon (0.38) was noticed under no fertilized plot. A nutrient availability, irrespective of the nutrient and organic carbon, was higher in plots receiving a nutrient applications in comparison to control plots. This might have happened to go to addition of a nutrients from external sources, a better root proliferation and favorable conditions for soil microbes to increase in nutrient transformations [22] also opined in an increase in adding of nitrogen fixing bacteria with a nutrient applications. Further, increase in the P and K status of soils might have been attributed to their fixation from added sources from soil solution to exchange sites/fixations as advocated by Prasad B. [23]. A similar observations have been made by Gogoi B., [24].

Table 1. Evaluation of the potential of smart fertilizers on the growth attribute and yield at the harvest of wheat

S. No.	Treatments	Plant population (No m ⁻²)	Plant height (cm)	Number of tillers m ⁻¹ row length	Dry matter accumulation (g m ⁻¹)	Grain Yield (q ha ⁻¹)
T ₁	Control	236.8	79.4	52.5	173.7	28.3
T ₂	NPK- (150:60:40)	276.9	100.8	62.1	264.6	49.1
T ₃	100 % NPK + Nano Zn spray	311.5	111.1	69.7	297.6	56.7
T ₄	100 % NPK + Bio-stimulant spray	305.9	109.2	68.4	293.5	55.8
T ₅	75 % NPK + NPK Consortia	263.9	98.1	59.2	260.2	43.5
T ₆	75 % NPK + NPK spray	281.0	100.6	61.9	265.8	45.1
T ₇	75 % NPK + NPK Consortia + Nano N spray	287.6	102.1	63.7	275.7	49.4
T ₈	75 % NPK + NPK Consortia + NPK spray	293.1	104.1	65.3	281.2	52.2
T ₉	75 % NPK + NPK Consortia + NPK spray +Bio-stimulant spray	299.6	103.3	65.6	287.1	53.5
T ₁₀	75 % NPK + NPK Consortia + NPK spray + Bio-stimulant spray + Nano Zn spray	307.8	110.6	68.9	294.0	55.9
T ₁₁	75 % NPK + NPK Consortia + Nano Zn spray	294.2	104.1	65.1	277.1	50.6
T ₁₂	75 % NPK + NPK Consortia +Nano N spray + Nano Zn spray	304.6	106.5	67.9	289.7	54.8
	SEm±	8.5	2.7	2.3	7.7	1.8
	CD (p = 0.05)	25.3	7.9	6.9	22.8	5.5

Table 2. Evaluation of the potential of smart fertilizers on available nutrients and organic carbon after harvest of wheat

S. No.	Treatments	Available nutrients (kg ha ⁻¹)			Available zinc (mg kg ⁻¹)	Organic carbon (%)
		Nitrogen	Phosphorus	Potassium		
T ₁	Control	174.5	10.8	132.7	0.79	0.38
T ₂	NPK- (150:60:40)	209.2	13.1	154.8	0.8	0.41
T ₃	100 % NPK + Nano Zn spray	196.7	14.1	135.1	0.82	0.42
T ₄	100 % NPK + Bio-stimulant spray	211.8	15.2	143.6	0.81	0.47
T ₅	75 % NPK + NPK Consortia	193.7	12.9	154.0	0.8	0.42
T ₆	75 % NPK + NPK spray	205.5	12.7	151.5	0.82	0.40
T ₇	75 % NPK + NPK Consortia + Nano N spray	196.6	12.7	145.8	0.82	0.48
T ₈	75 % NPK + NPK Consortia + NPK spray	189.0	11.4	139.2	0.84	0.48
T ₉	75 % NPK + NPK Consortia + NPK spray +Bio-stimulant spray	189.5	12.1	147.8	0.83	0.46
T ₁₀	75 % NPK + NPK Consortia + NPK spray + Bio-stimulant spray + Nano Zn spray	196.2	11.1	149.1	0.86	0.49
T ₁₁	75 % NPK + NPK Consortia + Nano Zn spray	210.9	12.2	148.6	0.87	0.48
T ₁₂	75 % NPK + NPK Consortia +Nano N spray + Nano Zn spray	185.0	12.0	148.4	0.85	0.49
	SEm±	7.0	0.4	5.2	0.029	0.02
	CD (p = 0.05)	20.5	1.3	NS	NS	0.05

4. CONCLUSION

From the above discussed future need for food and concern to soil fertility degradation due to a higher doses of inorganic fertilizers. The application of 75 % NPK + NPK Consortia + NPK spray + Bio-stimulant spray + Nano Zn spray in wheat can achieve a higher growth and yield with a better availability of a nutrients in soil for the future generations.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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