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The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; 12(12): 2451-2457

www.thepharmajournal.com
Received: 14-09-2023
Accepted: 20-11-2023

Swati H Patel
Department of Soil Science and Agricultural Chemistry, B. A. College of Agriculture, Anand Agricultural University, Anand, Gujarat, India

JK Parmar
Department of Soil Science and Agricultural Chemistry, B. A. College of Agriculture, Anand Agricultural University, Anand, Gujarat, India

AS Bhanvadiya
Department of Agronomy, B. A. College of Agriculture, Anand Agricultural University, Anand, Gujarat, India

Sanjay Makwana
Department of Agronomy, B. A. College of Agriculture, Anand Agricultural University, Anand, Gujarat, India

Aishwarya Maheta
Department of Soil Science and Agricultural Chemistry, B. A. College of Agriculture, Anand Agricultural University, Anand, Gujarat, India

Corresponding Author:
Swati H Patel
Department of Soil Science and Agricultural Chemistry, B. A. College of Agriculture, Anand Agricultural University, Anand, Gujarat, India

Effect of Nano NP, Nano P and recommended dose of fertilizers on growth, yield and nutrient content of wheat (*Triticum aestivum* L.) in field condition

Swati H Patel, JK Parmar, AS Bhanvadiya, Sanjay Makwana and Aishwarya Maheta

Abstract
Nano fertilizers are the important tools in agriculture to improve crop growth, yield and quality parameters with increase nutrient use efficiency, reduce wastage of fertilizers and cost of cultivation. Nanostructure fertilizer exhibits novel physico-chemical properties, which determines their interaction with biological substances and processes. The application of nano technological formulation to agricultural crop inputs is one of the proposed tools for sustainable intensifications. The present experiment was carried out at Regional Research Station, Anand Agricultural University, Anand (Gujarat) during *rabi* season of the year 2021-22 and 2022-23. The experiment was comprised of four levels of nano NP (0, 500, 1000 and 2000 ppm) and three levels of nano P (0, 500 and 1000 ppm) as well as a treatment having recommended dose of fertilizers was also taken for the comparison. Altogether, there were 12 treatment combinations and RDF laid out in factorial randomized block design (F-RBD) with three replications. The soil of experimental field was low in organic carbon content and available N. The foliar spray of nano NP and nano P was carried out at 21, 35 and 60 DAS. Result showed that wheat growth, yield, nutrient content and uptake were registered significantly higher with foliar application of $NP_3 + P_2$ (nano NP @ 2000 ppm + nano P @ 1000 ppm) at 21, 35 and 60 DAS over the other treatments. However, in comparison of nano particles and recommended dose of fertilizers, the RDF was significantly superior in terms of grain and straw yield. However, it is noticed that if these nutrients (*i.e.* N and P) are supplemented through only nano particles, the nutrients are likely to be depleted from the soil reserve to cause nutrient mining over the years. Hence, sole application of nano particles would have disadvantage over soil application in maintaining soil fertility status and thereby soil health.

Keywords: Nano fertilizer, growth and nutrient content

Introduction
Fertilizers have an axial role in enhancing the food production in developing countries especially after the introduction of high yielding and fertilizer responsive crop varieties *etc*. In spite of this, it is known that yields of many crops have begun to depression as a result of imbalanced fertilization and decrease in soil organic matter. In India, the total consumption of nitrogenous fertilizer is about 17 million tons (Doody, 2020) [4]. To address these problems, there is a need to explore one of the frontier technologies such as 'Nanotechnology' to precisely detect and deliver the correct quantity of nutrients that promote productivity while ensuring environmental safety and higher use efficiency.
Nano science has brought revolution in different fields by helping develop processes and products that are hardly possible to evolve through conventional methods. The nanotechnology aided applications have the potential to change agricultural production by allowing better management and conservation of inputs. It deals with the matter at Nano scale dimensions. x2019) [9]. Nano fertilizers were produced as a potential solution to reduce fertilizer loss in the environment and increase fertilizer use efficiency for crop production, hence decreasing the recommended dose of traditional fertilizers. Nano fertilizers are synthesized or modified form of traditional fertilizers, fertilizers bulk materials or extracted from different vegetative or reproductive parts of the plant by different chemical, physical, mechanical or biological methods with the help of nanotechnology used to improve soil fertility, productivity and quality of agricultural produces. Since N fertilization exhibits universal response in crops besides low price of urea due to decontrol (subsidized rate), farmers started using nitrogenous

fertilizers particularly urea heavily which has led to the current NPK ratio of 8.2:3.2:1 while optimal ratio is stipulated as 4:2:1. This is very serious issue causing nitrate pollution in ground water and eutrophication in aquatic system. This necessitates to develop slow release fertilizers to regulate the nitrification processes thereby N availability be sustained during the crop period. On the other hand, for P fertilizers, which are derived from mineral deposits, concerns are associated with limited supplies both geographically and quantitatively on a global scale. The issues of pollution of surface waters are pertinent to all N, P and K fertilizers.

Wheat (*Triticum aestivum* L.) is the second most important cereal staple crops, after rice and it contributes significantly to total cereal production contributes nearly (*i.e.*, 35% to the national food basket) and country's food security. Productivity of wheat can only be enhanced by application of scientific tools and techniques in agriculture. Modern science basically deals with three areas *i.e.* information technology, biotechnology and nanotechnology. These three sciences proved their worth in every sector of society, but agriculture is still lagging behind. Since, the soil application of nitrogen and phosphorus nano-fertilizers is not much accepted by scientists, but foliar spray is effective in increasing growth of crops throughout their life period.

Materials and Methods

The nano NP and nano P having particle size (0 to 709 nm), count rate (kcps) (0 to 287), poly dispersity index (0 to 0.46) and zeta potential (0 to -57.88 mV) were found in standard range of nano particles, when it synthesized using direct precipitation method and characterized through DLS and FTIR. The experiment was comprised of four levels of nano NP (0, 500, 1000 and 2000 ppm) and three levels of nano P (0, 500 and 1000 ppm) as well as a treatment having recommended dose of fertilizers was also taken for the comparison. Altogether, there were 12 treatment combinations and RDF laid out in factorial randomized block design (F-RBD) with three replications in field condition at Regional Research Station, AAU, Anand during *rabi* season of the year 2021-22 and 2022-23. Foliar application of nano NP and nano P was carried out at 21, 35 and 60 DAS.

Table 1: Initial physico – chemical properties of the soil used for field study

Sr. No.	Properties	Initial value
Physical properties		
1	Mechanical analysis (International pipette method)	(0-15 cm)
	Clay (%)	7.00
	Silt (%)	11.05
	Fine sand (%)	78.10
	Coarse sand (%)	1.95
	Bulk density (g/cc)	1.31
	Water holding capacity (%)	38.05
2	Texture	Loamy sand
Chemical properties		
3	pH (1:2.5)	8.0
4	EC (1:2.5) (dS/m)	0.18
5	Organic carbon (%)	0.40
6	Available N (kg/ha)	162
7	Available P_2O_5 (0.5 M $NaHCO_3$ extractable-P) (kg/ha)	39.45
8	Available K_2O (NH_4OAc extractable-K) (kg/ha)	270
9	Available S (mg/kg)	8.95

Sample collection and processing

Soil and plant sampling

Representative soil samples at 0-15 cm depth were collected initially from the entire experimental site. The soil samples were prepared by mixing the soil collected from four spots randomly. The soil samples were air-dried and ground to pass through a 2 mm sieve. The samples were stored in polythene bags for further analysis. After harvest of the crop, wheat grain and straw samples were taken for analysis. The samples were dried in paper bags at 65 ^{0}C till constant weight in a hot air oven and preserved for further analysis. The processed samples were preserved in airtight polyethylene bags for further analysis.

Methods of analysis

Soil analysis

The initial soil samples were analyzed for important soil properties *viz*., pH, EC, OC, available nutrients *viz*., N, P_2O_5, K_2O determined as per the standard methods (Table 2).

Plant analysis: Dried plant samples (straw and grain) were grinded in a stainless-steel grinder and digested with di-acid mixture (HNO_3: $HClO_4$ – 4:1) and volume was made with double distilled water (Lindsay and Norvell, 1978). The extract was filtered through Whatman filter paper No. 42. The filtrate of plant samples was used for determination of P_2O_5 and K_2O (Table 2).

Table 2: Chemical parameters studied during the experiment

Sr. No.	Parameters	Extraction method
Soil analysis		
1	pH (1:2.5 soil: water)	Potentiometric
2	EC (1:2.5 soil: water)	Conductimetric
3	Organic carbon (OC)	Chromic acid wet oxidation method
4	Available N	Alkaline $KMnO_4$ (0.32%) Method
5	Available P_2O_5	0.5 M $NaHCO_3$, pH 8.5, Spectrophotometry

6	Available K_2O	1N NH_4OAC, pH 7.0 (Flame photometric)
Plant analysis		
1	Nitrogen	Kjeldahl Method
2	Phosphorus	Vanadomolybdo phosphoric acid yellow colour method
3	Potassium	Flame photometry Method

Results and Discussion

Effect of nano NP

Plant population per meter row length at 21 DAS; plant height at 21 DAS and at harvest; K content in grain and straw; EC, pH, OC, available N, P_2O_5 and K_2O after harvest of wheat were found to be non-significant with different levels of nano NP.

Significantly the highest plant height at 45 DAS (56.50 cm), number of total tiller (304 per meter row length) and spike length (10.02 cm) at harvest was recorded under foliar application of nano NP (2000 ppm) in pooled data over rest of treatments. It is might be due to that the increase in plant height at foliar feeding of nano fertilizer are attributed to the role of these nutrients in stimulating plant growth. These essential elements are required for optimum growth of the plant to complete its life cycle. These results were in close conformity with finding of Al-Juthery *et al.* (2018) [2] in wheat, Rawate *et al*. (2022) [8] in wheat and Maheta *et al*. (2023) [6] in maize.

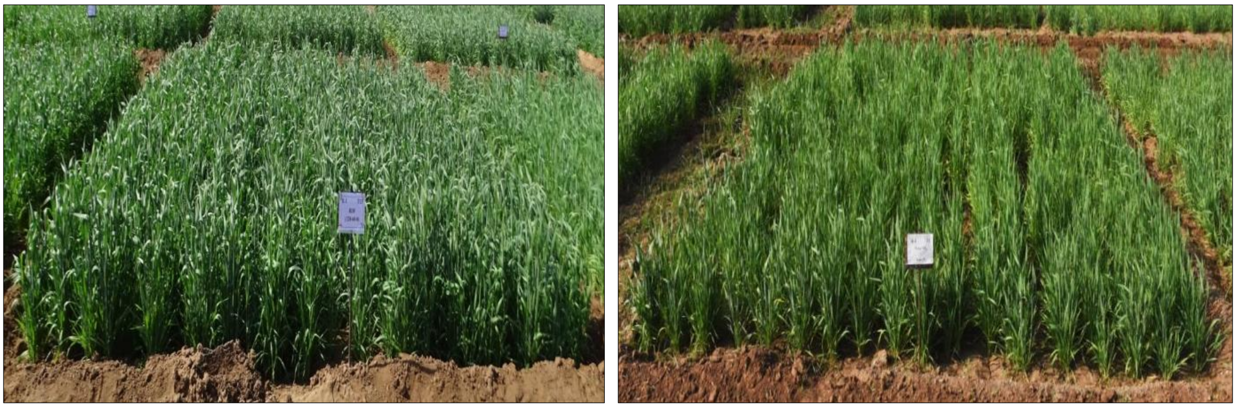

Fig 1: Effect of foliar application of nano NP and nano P fertilizers on plant growth at 45 DAS of wheat (RDF and NP_0+P_0)

The significantly highest grain yield (4590 kg/ha) was recorded under the foliar application of nano NP @ 2000 ppm. It might be due to that nano NP fertilizer promotes the plant to absorb the water from soil and fasten the nutrients supply, so the photosynthesis is improved, thus the production was also increased. The similar results were also found by Chandana *et al.* (2021) [3] in rice, Rawate *et al*. (2022) [8] in wheat and Maheta *et al*. (2023) [6] in maize. While significantly higher straw yield (6693 kg/ha) was recorded under the foliar application of nano NP @ 2000 ppm, but it was at par with treatment application of nano NP @ 1000 ppm (6408 kg/ha) in pooled results. This may be attributed with foliar application might be due to quick absorption by plant and easiness of translocation, which aided in better rates of photosynthesis and more dry matter accumulation, that give higher straw yield.

Results of foliar application of nano NP (2000 ppm) had significantly higher N content in wheat grain (2.18%) and straw (0.99%), but it was at par with treatment application of nano NP @ 1000 ppm (2.08% and 0.89%, respectively) in pooled result over the rest of treatments.

Table 3: Effect of foliar application of nano NP and nano P fertilizers on plant population, plant height, number of total tiller and spike length of wheat on pooled basis

Treatments	Plant population at 21 DAS	Plant height (cm) at 21 DAS	Plant height (cm) at DAS	Plant height (cm) at harvest	Number of total tiller at harvest	Spike length (cm)	Grain yield (kg/ha)	Straw yield (kg/ha)
Level of Nano NP (ppm)								
NP_0 (0)	47.87	22.70	45.72	69.64	273	8.15	3736	5523
NP_1 (500)	48.76	22.92	50.59	70.71	280	8.91	3987	5936
NP_2 (1000)	48.91	22.98	53.02	71.14	289	9.52	4291	6408
NP_3 (2000)	49.24	23.14	56.50	71.78	304	10.02	4590	6693
S.Em. ±	0.868	0.426	0.801	1.178	4	0.17	89	152
CD(P=0.05)	NS	NS	2.284	NS	13	0.49	253	432
Level of Nano P (ppm)								
P_0 (0)	47.89	22.60	49.96	70.36	282	8.87	4051	5964
P_1 (500)	49.03	23.05	51.55	70.65	287	9.12	4153	6179
P_2 (1000)	49.17	23.15	52.87	71.43	291	9.45	4249	6278
S.Em. ±	0.751	0.369	0.693	1.020	4	0.15	77	131
CD(P=0.05)	NS	NS	1.978	NS	NS	0.42	NS	NS
Interaction								
NP X P	NS	NS	NS	NS	NS	NS	NS	NS

Y X NP	NS	NS	NS	NS	NS	NS	NS	NS
Y X P	NS	NS	NS	NS	NS	NS	NS	NS
Y X NP X P	NS	NS	NS	NS	NS	NS	NS	NS
S.Em ±	1.503	0.737	1.387	2.040	8	0.29	154	263
CD(P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
CV %	7.56	7.87	6.60	7.05	6.54	7.90	9.08	10.48

The significantly highest nitrogen uptake by wheat grain (100.04 kg/ha) was found with foliar application of nano NP @ 2000 ppm in pooled data. Whereas foliar application of nano NP @ 2000 ppm had significantly higher N uptake by wheat straw (66.45 kg/ha), but it was at par with foliar application of nano NP @ 1000 ppm (57.01 kg/ha in pooled result) as compared to other treatments. The reason behind this is improvement in wheat yield caused by hydroxyapatite coating and foliar spray may have been due to increased N use efficiency so one possible approach to improve the nitrogen losses from the surface applied urea is to coat it with hydroxyapatite. Recovery efficiency of nitrogen was increased using foliar with hydroxyapatite urea that increase N content in wheat grain. This finding is in accordance with the finding of Abdel and Fahmy (2017) [1] were reported in wheat grain.

Significantly higher P content in wheat grain (0.229%) and straw (0.186%) was found with foliar application of nano NP @ 2000 ppm in pooled. But it was at par with foliar application of nano NP @ 1000 ppm (0.219% and 0.183%, respectively) over the other treatments. The content of nutrients was found to be increased with the foliar application of nano NP, which might be due to the quick absorption and rapid transport of nano nutrients in the plant. These results are in consonance with Al-Juthery *et al*. (2018) [2] in wheat.

Table 4: Effect of foliar application of nano NP and nano P fertilizers on nitrogen content and uptake by wheat grain and straw on pooled basis

Nitrogen content (%)			Nitrogen uptake (kg/ha)	
Treatments	**Grain**	**Straw**	**Grain**	**Straw**
RDF	2.17	0.99	102.68	69.35
Level of Nano NP (ppm)				
NP_0 (0)	1.82	0.66	68.36	36.15
NP_1 (500)	1.94	0.78	77.70	46.50
NP_2 (1000)	2.08	0.89	89.17	57.01
NP_3 (2000)	2.18	0.99	100.04	66.45
S.Em. ±	0.04	0.03	2.332	2.727
CD (P=0.05)	0.11	0.16	6.646	12.273
Level of Nano P (ppm)				
P_0 (0)	1.94	0.79	79.39	47.69
P_1 (500)	2.01	0.84	83.91	52.09
P_2 (1000)	2.06	0.86	88.14	54.81
S.Em. ±	0.03	0.01	2.019	1.392
CD (P=0.05)	0.09	0.044	5.756	3.972
Interaction				
NP X P	NS	NS	NS	NS
Y X NP	NS	Sig.	NS	Sig.
Y X P	NS	NS	NS	NS
Y X NP X P	NS	NS	NS	NS
S.Em ±	0.06	0.03	4.039	2.785
CD (P=0.05)	NS	NS	NS	NS
CV %	8.00	9.02	11.80	13.24

The foliar application of Nano NP @ 2000 ppm had significantly the highest P uptake by wheat grain (10.53 kg/ha) in pooled data. Whereas foliar application of nano NP @ 2000 ppm had significantly higher P uptake by wheat straw (12.46 kg/ha), But it was at par with treatment application of nano NP @ 1000 ppm (11.79 kg/ha) in pooled data over rest of treatments. This may be due to that coating of nano fertilizer are capable of regulating the release of nutrients from the fertilizer and nano particles have both positive and negative charged binding site that nanoparticles triggered metabolic activity in plants which results in increased uptake and translocation. This finding is in accordance with the finding of Kannoj *et al*. (2022) [5] in wheat.

Significantly the highest K uptake by wheat grain (22.56 kg/ha in pooled data) was found with treatment application of nano NP @ 2000 ppm as compared to other treatments. Whereas foliar application of nano NP @ 2000 ppm had significantly higher K uptake by wheat straw (71.31 kg/ha), but it was at par with nano NP @ 1000 ppm (67.91 kg/ha) in pooled basis as compared to rest of treatments. Nano-particles enter the plant system by interacting with ionic channels, transport proteins, aquaporin, forming new pores, or as a result of endocytosis, all of which result in enhancing the distribution of nutrient absorbed from soil, which ultimately increased the higher nutrient concentrations in plant. This result was supported by Lahari *et al*. (2021) [10] in wheat.

Effect of nano P

The plant population at 21 DAS; plant height at 21 DAS and at harvest; number of total tillers at harvest (per meter row length); grain yield (kg/ha); straw yield (kg/ha); K content and uptake by grain and straw; EC, pH, OC, available N, P_2O_5 and K_2O after harvest of wheat were found to be non-significant with different levels of nano P.

Table 5: Effect of foliar application of nano NP and nano P fertilizers on phosphorus content and uptake by wheat grain and straw pooled basis

	Phosphorus content (%)		Phosphorus uptake (kg/ha)	
Treatments	**Grain**	**Straw**	**Grain**	**Straw**
RDF	0.230	0.191	10.88	13.38
Level of Nano NP (ppm)				
NP_0 (0)	0.201	0.159	7.51	8.81
NP_1 (500)	0.216	0.169	8.63	10.03
NP_2 (1000)	0.219	0.183	9.42	11.79
NP_3 (2000)	0.229	0.186	10.53	12.46
S.Em. ±	0.004	0.003	0.27	0.354
CD (P=0.05)	0.012	0.010	0.78	1.010
Level of Nano P (ppm)				
P_0 (0)	0.203	0.161	8.27	9.66
P_1 (500)	0.208	0.172	8.69	10.69
P_2 (1000)	0.237	0.190	10.11	11.97
S.Em. ±	0.003	0.003	0.24	0.307
CD (P=0.05)	0.010	0.008	0.67	0.874
Interaction				
NP X P	NS	NS	NS	NS
Y X NP	NS	NS	NS	NS
Y X P	NS	NS	NS	NS
Y X NP X P	Sig.	NS	Sig.	NS
S.Em ±	0.007	0.006	0.47	0.614
CD (P=0.05)	NS	NS	NS	NS
CV %	8.01	8.11	12.82	13.96

The plant height at 45 DAS (52.87 cm) and spike length (9.45 cm) was found that an application of nano P @ 1000 ppm registered significantly higher in pooled results and at par relation with foliar application of nano P @ 500 ppm (51.55 cm and 9.12 cm, respectively) over rest of treatments. The reason behind this kind of behaviour could be explained on the basis of the role of P in plant body. Phosphorus being an essential part of nucleic acids and proteins which are very important in promoting the growth. This result was supported by finding of Maheta *et al*. (2023) [6] in maize.

Nitrogen content and uptake by wheat grain and straw was found that an application of treatment nano P @ 1000 ppm show significantly a higher N content and uptake by wheat grain (2.06% and 88.14 kg/ha) and straw (0.86% and 54.81 kg/ha) during pooled results, but it was at par with foliar application of nano P @ 500 ppm (2.01% and 83.91 kg/ha in grain) (0.84% and 52.09 kg/ha in straw), respectively as compared to control. It might be due to that evaluated hydroxyapatite and urea coated HAP in foliar individually or combined act as a slow release strategy for sustained release of nitrogen into the plant. Thus, increase its concentration.

The application of treatment nano P @ 1000 ppm registered significantly the highest P content and uptake by wheat grain (0.237% and 10.11 kg/ha) and straw (0.190% and 11.97 kg/ha), respectively in pooled results as compared to other treatments. It is might be due to that applying nano-hydroxyapatite (nHAP) increased P concentration and as the result of orthophosphates released from dissolved nHAP, allowed full functionality restoration of P in treated plants. Nano-particles enter the plant system by interacting with ionic channels, transport proteins, aquaporin, forming new pores, or as a result of endocytosis, all of which result in higher nutrient concentrations in plant. This result was conformity with the finding of Poudel *et al*. (2023) [7] in wheat.

Table 6: Effect of foliar application of nano NP and nano P fertilizers on potassium content and uptake by wheat grain and straw pooled basis

	Potassium content (%)		Potassium uptake (kg/ha)	
Treatments	**Grain**	**Straw**	**Grain**	**Straw**
RDF	0.48	1.06	22.71	74.25
Level of Nano NP (ppm)				
NP_0 (0)	0.46	1.03	17.19	56.76
NP_1 (500)	0.47	1.05	18.96	62.56
NP_2 (1000)	0.47	1.06	20.40	67.91
NP_3 (2000)	0.49	1.06	22.56	71.31
S.Em. ±	0.01	0.025	0.656	2.106
CD (P=0.05)	NS	NS	1.869	6.007
Level of Nano P (ppm)				
P_0 (0)	0.46	1.04	18.78	62.42
P_1 (500)	0.48	1.05	19.97	65.27
P_2 (1000)	0.48	1.06	20.58	66.21
S.Em. ±	0.01	0.021	0.568	1.824
CD (P=0.05)	NS	NS	NS	NS
Interaction				
NP X P	NS	NS	NS	NS
Y X NP	NS	NS	NS	NS
Y X P	NS	NS	NS	NS
Y X NP X P	NS	NS	NS	NS
S.Em ±	0.02	0.042	1.136	3.647
CD (P=0.05)	NS	NS	NS	NS
CV %	9.85	9.88	14.07	13.82

Table 7: Effect of foliar application of nano NP and nano P fertilizers on electrical conductivity, pH and organic carbon of soil after harvest of wheat

	EC		pH		OC	
Treatments	**2021**	**2022**	**2021**	**2022**	**2021**	**2022**
Initial	0.18	0.19	8.00	8.01	0.40	0.40
Level of Nano NP (ppm)						
NP_0 (0)	0.17	0.18	8.10	8.11	0.40	0.40
NP_1 (500)	0.18	0.19	8.12	8.13	0.40	0.42
NP_2 (1000)	0.18	0.19	8.13	8.27	0.41	0.44
NP_3 (2000)	0.18	0.20	8.14	8.48	0.43	0.44
S.Em. ±	0.04	0.04	0.21	0.31	0.01	0.02
CD(P=0.05)	NS	NS	NS	NS	NS	NS
Level of Nano P (ppm)						
P_0 (0)	0.18	0.19	8.12	8.21	0.41	0.42
P_1 (500)	0.18	0.19	8.11	8.23	0.41	0.43
P_2 (1000)	0.18	0.19	8.13	8.30	0.42	0.43
S.Em. ±	0.04	0.03	0.18	0.27	0.01	0.01
CD(P=0.05)	NS	NS	NS	NS	NS	NS
Interaction						
NP X P	NS	NS	NS	NS	NS	NS
S.Em ±	0.08	0.08	0.36	0.54	0.02	0.03
CD(P=0.05)	NS	NS	NS	NS	NS	NS
CV %	8.69	7.97	7.65	11.36	9.14	11.27

Table 8: Effect of foliar application of nano NP and nano P fertilizers on available nitrogen, phosphorus and potassium of soil after harvest of wheat

	Available nitrogen		Available phosphorus		Available potassium	
Treatments	2021	2022	2021	2022	2021	2022
Initial	162.32	166.81	39.45	40.85	270.78	285.52
RDF	172.98	174.77	42.96	44.48	283.65	294.78
Level of Nano NP (ppm)						
NP_0 (0)	170.74	171.11	39.90	41.01	267.19	267.66
NP_1 (500)	168.99	164.94	38.85	39.36	277.48	277.51
NP_2 (1000)	163.77	160.97	37.98	36.91	293.56	290.28
NP_3 (2000)	160.28	155.31	36.66	34.98	300.32	304.22
S.Em. ±	4.14	5.50	1.53	1.65	10.44	10.50
CD(P=0.05)	NS	NS	NS	NS	NS	NS
Level of Nano P (ppm)						
P_0 (0)	168.56	164.31	39.23	39.07	281.84	282.47
P_1 (500)	165.95	163.06	38.10	37.87	283.52	284.63
P_2 (1000)	163.33	161.87	37.72	37.25	288.56	287.65
S.Em. ±	3.59	4.77	1.33	1.45	9.04	9.10
CD(P=0.05)	NS	NS	NS	NS	NS	NS
Interaction						
NP X P	NS	NS	NS	NS	NS	NS
S.Em ±	7.17	9.53	2.65	2.90	18.08	18.19
CD(P=0.05)	NS	NS	NS	NS	NS	NS
CV %	7.49	10	11.99	12.98	11.00	11.06

Control *vs.* rest

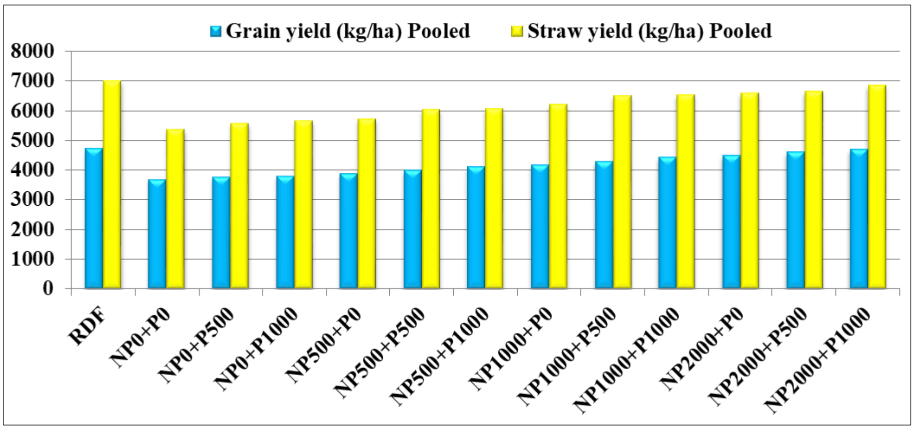

Fig 2: Effect of foliar application of nano NP and nano P fertilizers on grain and straw yield of wheat (control *vs.* rest)

The grain and straw yield (4732 and 7005 kg/ha, respectively) was observed significantly highest in application of RDF (control) over rest of treatments (4151 and 6140 kg/ha, respectively) in pooled result. The grain and straw yield was increased by 13.99 and 14.08% in RDF (control) over the rest at harvest of wheat in pooled data.

Conclusion

From the present study, following inferences are emerged that wheat growth, yield, nutrient content and uptake were registered significantly higher with foliar application of NP_3 + P_2 (nano NP @ 2000 ppm + nano P @ 1000 ppm) at 21, 35 and 60 DAS over the other treatments. However, in comparison of nano particles and recommended dose of fertilizers, the RDF was significantly superior in terms of grain and straw yield. However, it is noticed that if these nutrients (*i.e.* N and P) are supplemented through only nano particles, the nutrients are likely to be depleted from the soil reserve to cause nutrient mining over the years. Hence, sole application of nano particles would have disadvantage over soil application in maintaining soil fertility status and thereby soil health.

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