Impact of Nano-Urea Application on Wheat Yield and Soil Properties: A Sustainable Approach to Nutrient Management

ABSTRACT

A field experiment was conducted during the winter (*rabi*) season of 2022–23 at Dugurpur village Nuaon Block under On Farm Trial by Krishi Vigyan Kendra, Kaimur, to investigate the Impact of Nano-Urea Application on Wheat Yield and Soil Properties.The experiment was tested in a randomized block design with 2-nano-urea based treatment,viz. farmers practice (100% RDF), 50% of RDN & 100% PK + nano urea @4ml/lt. water (Single spray at 35 DAS), 50% of RDN & 100% PK + 2 sprays of Nano Urea at (35 DAS) and (60-65DAS) @ 4 ml/lt water. Results revealed that, yield attributes were significantly higher with 50% RDN& 100% PK along with nano urea. This treatment also resulted in 1.6 and 4.2% more grain yield with 100% RDF (33.14 q/ha).The effective tillers/m2 and number of grains/spike whichresulted in significantly higher grain yield. Thus, 50% RDN & 100% PK along with 50% of RDN & 100% PK + 2 sprays of Nano Urea at (35 DAS) and (60-65DAS) @ 4 ml/lt water are the more productive options for wheat-growingfarmers keeping view of the uprising cost and crisis of urea.

***Key words*:** IFFCO Nano-urea, Wheat, Yield attributes, Soil physico chemical properties

1. Introduction

"Wheat (*Triticum aestivum* L.) is the most important cereal crop of the world and the second most important crop in India. To keep pace with the annual population growth rate of India, i.e. 0.97%, and to meet the future wheat demand of India by 2050, i.e. 140 million tonnes, the productivity from present level of 3.3 t/ha to 4.7 t/ha and production of wheat by 46% have to be increased" (Ramadas *et al.* 2019). The average annual wheat production in Bihar is approximately 4-4.5 million tonnes. Nitrogen is most important factors responsible for low productivity of wheat. Wheat (*Triticum aestivum* L.) is the most important and widely grown cereal crop of the globe which is grown since prehistoric times. It is referred to as the "king of cereals" and is the oldest cereal food crop belonging to the family Poaceae. "Globally wheat (*Triticum spp*.) annual production of 756.40 million metric tons from 240 million hectares of land" (Ashik et al., 2023).India is the second largest producer of wheat in the world. Wheat is grown in India on 33.61 m ha and produces of 106.21mt with national average yield of 3160 kg ha^{-1} during 2019-20 (Anonymous, 2020). In India, wheat is farmed on around 31.76 million hectares, yielding 108.75 million tonnes with a productivity of 34.24 quintal ha^{-1} (Anonymous, 2021). In the state of Rajasthan, the wheat crop covers an area of 34.97 lakh hectares with an annual production of 10.92 million tonnes and average productivity of 3.5 tonnes ha^{-1}. Rajasthan state is in the fifth position in terms of wheat production after Uttar Pradesh, Punjab, Haryana and Madhya Pradesh (Anonymous, 2021).

"After carbon, hydrogen and oxygen, nitrogen (N) is one of the important elements in plants because of its key part in chlorophyll production, which is basic for the photosynthesis process. Also, nitrogen is part of different enzymatic proteins that catalyze and regulate plant-development processes" (Sinfield*et al.*, 2010). "Besides, nitrogen contributes to the generation of chemical components that secure against parasites and plant diseases" (Hoffland*et al.*, 2000). At last, crop yield and biomass are profoundly affected by N fertilization (Tremblay *et al.*, 2011). Plants absorb nitrogen as a mineral nutrient primarily from soil, and it can be may come in the form of ammonium (NH_4^+) and nitrate (NO_3^-) (Taiz and Zeiger 2010). Nonetheless, soil N supply is often limited (Vigneau*et al.*,2011), which forces farmers to increase the amount of N fertilizers in order to accomplish better crop yield. The conventional urea is less efficient and more harmful to the environment; however, recently developed nano-fertilizers like nano-urea enhanced the nutrient-use efficiency with very low rate of application, reduced input cost, environmentally safe and most importantly enhanced productivity and quality (Kiran and Samal, 2021; Kumar *et al*., 2021). Foliar application of nano-fertilizers significantly increased yield of the crop (Tarafdar*et al*.,2012).

"Nano fertilizers which are environment-friendly or smart fertilizers with the potential to increase the application rates of fertilizers and reduce the loss of nutrients from it mainly phosphorous and nitrogen" (Dimkpa and Bindraban 2018). Mandal *et al*., 2024 reported that nitrogen is a significant constituent of chlorophyll, the photosynthesis in green leaves might be increased by nitrogen fertilization, which helps in better translocation from leaves to grains. Nanotechnology emerged as an innovative solution for addressing the issue of low or declining NUE (nutrient use efficiency) with a minimal environmental footprint (Kumar *et al*., 2021). The nanoparticles release nutrients in a controlled manner to plant parts where nitrogen is required, thereby reducing the usage (up to 50%), increasing efficiency, and reducing wastage in the environment. There has been a lot of interest in using NPs (Nanoparticles) on plants for agricultural management during the past few years. So, keeping these facts in view, it was essential to see the effect of irrigation regimes and nano-urea-based nitrogen management practices on various growth parameters of wheat. However, 50–70% of nitrogenous fertilizers applied through conventional fertilization is either fixed in the soil or are lost to the environment due to volatilization, leaching and water runoff or they are incorporated as minerals in the soil through the action of microorganisms. Ironically, the unbalanced and haphazard use of inorganic fertilizers has a negative effect on the availability of nutrients to plants as well as on soil fertility and soil health resulting in lowering the productivity of crops and causing chronic diseases in human beings. Among the primary nutrients, nitrogen is the most crucial nutrient for crop productivity and it also plays a major role in agriculture.

"The usage of nano-enabled fertilizers may improve nutrient delivery efficiency in plants" (Chhipa, 2017). "These nanoscale fertilizers reduce nutrient losses due to leaching, and chemical alterations can be avoided to enhance nutrient use efficiency and environmental quality" (Raliya, 2017). "They are further characterized by their small size and large specific surface area, making them ideal materials in the manufacture of fertilizers called smart fertilizers after encapsulation with polymers or chelated to be slow release to suit the stages of a plant" (Shang, 2019).

IFFCO has introduced nano urea (liquid) nitrogen to address low or declining use efficiency of nitrogen. Nano urea – liquid (Nano Nitrogen) utilises the dynamics of shape, size, surface area and better assimilation. Its application enhances plant metabolic processes, promotes meristematic activities; ensures higher apical growth and leaf photosynthetic area, triggers enzymes, and induces mechanisms/pathways inside the plant for achieving the desired N levels in amino acids/ protein content, chlorophyll content, nucleic acid, photosynthates, etc.

Precise and targeted application of nitrogen through foliar application of nano urea – liquid (nano nitrogen) reduces urea losses; increases nutrient uptake efficiency; and addresses environmental issues of soil, air and water pollution. It results in better crop harvest with lesser nitrogen application per unit area thus, leading to better farm economics. Spraying of nano urea – liquid (nano nitrogen) meets 100 ppm N requirement of crop at critical growth stages and triggers positive crop response, fulfils its nutritional requirement and also improves nutrient availability in the rhizosphere.

2. Materials & Methods

2.1 Experiment site, Design & Field Management

A field experiment of On-Farm Trial was conducted during winter (rabi) season of 2022-23, to investigate the Effect of nano-urea on yield, yield attributes and soil physico-chemical properties of wheat (*Triticum aestivum*)at the Village Dugurpur, Block- Nuaon, District Kaimur, Bihar. The experiment was conducted in randomized block design with 8 replicates and 3 treatments. The soil of the experimental site was sandy loam (sand 53.4%, silt 19.8% and clay 26.8%) with electrical conductivity of 0.12 dS m^{-1} and soil pH of 6.89. The organic carbon 3.5., available N 111 kg ha^{-1}, available P 13 kg $ha^{-1}$and available K 113 kg ha^{-1}. The treatments were tested in a randomized block design with 3 main plot treatments, viz. Farmers Practice (100% RDF), 50% of RDN & 100% PK + nano urea @4ml/lt. water (Single spray at 35 DAS) and 50% of RDN & 100% PK + 2 sprays of Nano Urea at (35 DAS) and (60-65DAS) @ 4 ml/lt water. Wheat variety 'HD 2967' was shown on 25 November 2022 with a seed rate of 100 kg ha^{-1}, maintaining a row-to-row spacing of 22.5 cm along with basal dose of recommended dose of P and K, i.e. 60 kg P_2 O_5 and 40 kg K_2O ha^{-1}, applied uniformly technology option 01 and 02. 100% RDN, nitrogen was applied basal at 60 kg ha^{-1} and 2 equal splits of 30 kg ha^{-1}top-dressed at 25 DAS and at the maximum tillering, i.e. 60 DAS. In 50% RDN + 1 spray of nano-urea (at 35 DAS) treatment, nitrogen @ 30 kg ha^{-1} was applied basal, and rest 30 kg ha^{-1} top-dressed at 25 DAS as well as 1 spray of nano-urea was done at 35 DAS. In 50% RDN + 2 sprays of nano-urea (at 35 and 65 DAS) treatment, nitrogen was applied basal as 30 kg ha^{-1}, and rest 30 kg ha^{-1}as top-dressed at 25 DAS as well as 2 sprays of nano-urea was done at65 DAS. Nano-urea was applied by spraying @ 4 ml nano-urea/litre of water. Urea, Di ammonium phosphate and muriate of potash were used as a source of soil-applied N, P and K fertilizer respectively. At maturity, yield attributes and grain and straw yield of each plot recorded separately.

In laboratory thesesamples were analyzed using Mini Soil Testing Lab (MRIDA PARIKSHAK) developed by ICAR Indian Institute of Soil Science, Bhopal in collaboration with Nagarjuna Agrochemicals (NAC) Pvt. Ltd., Hyderabad (Srivastva *et al*., 2017).

2.2 IFFCO Nano urea

Indian Farmers Fertilizer Cooperative Limited (IFFCO) has recently developed a nano-urea in liquid form having particle size 20-50 nm, containing 4% nitrogen by weight (w/v) in its nano form and compared to the conventional granular urea, it has about 10000 times more surface area to volume size (Baboo, 2021). When sprayed on leaves nano-urea easily enters through stomata and other openings and is as similated by the plant cell and distributed through the phloem from source to sink inside the plant as per its need. One 500 mL bottle of nano-urea was considered equivalent to one bag of 50 kg prilled urea to meet the nitrogen requirement of the crop. A mixture of 2-4 mL nano urea per litre of water is recommended to spray on crop leaves at active growth stages.

3. Results and Discussion

3.1 Effect of Nano urea on yield and yield attributes of wheat

Plant height did not differ significantly among application of 50% RDN along with 1 spray and 2 spray of nano urea (Table 1& Fig. 1). Mandal *et al*., 2024 and Kumar *et al*., 2018 reported that there was no variation in the plant height among the irrigation treatments in crop growth. The main reason behind this was the occurrence of frequent rainfall during the vegetative growth stages of the crop.Theeffective tillers no./m2 increased significantly, minimum being in the farmers practice and the maximum in 50% RDN along with 2 spray 35 and 65 DAS of nano urea, which was 32% higher over the farmers practice. Grain yield of wheat increased significantly (Table 1& Fig. 2), the maximum was in 50% RDN + 2 spray of nano urea which yielded4, and 2% higher than farmers practice (100% RDF) and 50% RDN & 100% PK + 1soray of nano urea, respectively. The significantly higher spike length (Table 1) was recorded with application of 50% RDN along with 2 spray of nano urea (7.89 cm) followed by technology option 01 (50% RDN & 100% PK + 1soray of nano urea) which was 17% and 5% increase over farmers practice (100% RDF). Application of 50 % RDN and 100% PK along with 2 spray of nano urea (Tech. Op. 02) led to the production of maximum grains per spike (29.43), followed by50% RDN & 100% PK + 1spray of nano urea (27.63) which was 11% and 5% increased over farmers practice (26.41) show in table 2. Application of 50 % RDN and 100% PK along with 2 spray of nano urea resulted in highest test weight (36.70 g), which was closely followed by 50% RDN & 100% PK + 1spray of nano urea (35.94 g). Wheat grain yields recorded (Table 2& Fig 1) under 50% of RDN & 100% PK + nano urea @4ml/lt. water (Single spray at 35 DAS) and 50% of RDN & 100% PK + 2 sprays of Nano Urea at (35 DAS) and (60-65DAS) @ 4 ml/lt water statistically similar. The straw yield (Table 02) was maximum in 50% of RDN & 100% PK + 2 sprays of Nano Urea at (35 DAS) and (60-65DAS) @ 4 ml/lt water which was about 4% higher than that in the farmers practice 100% RDF (100:40:20) kg ha^{-1}were reported by (Tamrabet *et al.*, 2009).This may be due to nano urea which encourages the plant, root and shoot efficiency to absorb and translocate the available macro and micronutrients from soil, thereby enhancing the photosynthesis and target activity (Nair *et al.*, 2010). This, in turn, the productive tillers per hill and number of filled grains per panicle were significantly increased by the application of nano urea over conventional fertilizers.Mandal *et al.*, 2024 reported that Nano-urea should be applied at active growing stages of wheat to maintain the growth attributes at sufficient level. Foliar application of nano-urea was inept to meet 25 or 50% of RDN; hence, 100% RDN in 3 split doses was superior for enhancing the growth parameters of wheat. (Kumar *et al.*, 2020) also reported that the application of nano urea resulted highest grain yield was recorded with application of IFFCO liquid nano urea. The increased nutrient availability and appropriate nitrogen supply through nano urea, which permitted the crop growth and significantly improved yield. These results are similar with findings of Navya*et al*. (2022).

3.2 Effect of Nano urea on Soil Properties

The available N content in post harvest wheat soil (Table 3& Fig. 3) significantly with successive increase in foliar application of nano urea. The available phosphorus post harvest soil of wheat varied from 20.25 to 23.75 kg ha^{-1}. The maximum phosphorus content (23.75 kg ha^{-1}) was recorded with application of 50% of RDN & 100% PK + 2 sprays of Nano Urea at (35 DAS) and (60-65DAS) @ 4 ml/lt water followed by 50% of RDN & 100% PK + nano urea @4ml/lt. water (Single spray at 35 DAS) (23.0 kg ha^{-1}) which was 17 and 13% increased over farmer practice (20.25 kg ha^{-1}). The potassium content in soil was varied from 137.88 to 157.88 kg ha^{-1}. Application of 50% of RDN & 100% PK + 2 sprays of Nano Urea at (35 DAS) and (60-65DAS) @ 4 ml/lt water recorded maximum sulphur content (7.81 to 8.84 mg kg^{-1}) and minimum in Farmer practice (7.81 mg kg^{-1}). The micronutrient content zinc in post harvest soil of wheat was recorded maximum in 0.23 mg kg^{-1} technology option 1 and technology option 02 and minimum in farmer practice (0.15 mg kg^{-1}).The N in nano form especially provided at the later phases of the plant life cycle might also have resulted in higher available N, P K resulted in availability of nutrient for a longer period of time. In addition to this, the nano particles being very small in size are able to easily penetrate through the epidermis of foliage making them highly efficient. Similar results were obtained by Alam *et al.* (2010).

3.3 Effect of Nano urea on Economics of Wheat

Economics is the main parameter which finally decidesthe adoption levels at farming situations of any newly introduced technology by the farmers. It should be technically and economically viable. Therefore, the economicanalysis of the results is very important.The maximal net return (₹ 55,599) and B:C ratio (2.59) were fetched under the crop treated with 50% of RDN & 100% PK + 2 sprays of Nano Urea at (35 DAS) and (60-65DAS) @ 4 ml/lt water which was statistically comparable to 50% of RDN & 100% PK + nano urea @4ml/lt. water (Single spray at 35 DAS)andfarmers practice 100% RDF (100:40:20) kg ha^{-1} (Table4). The increase of net return and B:C ratio with the application of 50% of RDN & 100% PK + 2 sprays of Nano Ureawas5 and 3 per cent over Farmer Practice. Nano fertilizers may boost crop development and yield characteristics as well as make active photosynthetic activities and source-sink relationships which directly affect yield. Reduced urea treatment and efficient foliar nano fertilizer application led to lower cultivation costs, which in turn increased grain and straw yield and ultimately net return. In contrast, nano urea, when used as a partial replacement for conventional urea, did not provide the same benefits, indicating that more research is needed to fully understand its potential and optimize its use in nitrogen management strategies for long-term sustainability (Reddy *et al*., 2025).These results were consistent with the results(Manikandan *et al*., 2016) and (Kumar *et al*., 2020).

4. Conclusions

Results depicted the superiority of splitting two dose of nitrogen through nano-urea (33% replacement) in wheat crop for morphological, physiological, and yield attributes over Farmers Practice (N:P:K::100:40:20 kg ha^{-1}), which was also supported by the activities of N-metabolizing enzymes. Further, it was observed that 50% replacement of urea applied through 2 spray of nano-N (35 DAS and 60-65 DAS) was not found satisfactory in any case, either by soil application followed by single foliar spray. Nano-Nitrogen is the recent formulation of IFFCO and a partial substitution of urea dose with nano-nitrogen could be considered one of the promising alternatives for Indian intensive agriculture systems (rice–wheat cropping system).

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Table1 Effect of nano-urea-based nitrogen management on growth attributing characters of wheat

Treatments	Plant Height (cm)				Effective tillers (no./m²)	Spike length (cm)
	30 DAS	60 DAS	90DAS	At harvest	At harvest	At harvest
Farmers Practice (RDF: 100:40:20) kg ha^{-1}	16.90	38.53	70.67	72.50	234	6.76
50% of RDN & 100% PK + nano urea @4ml/lt. water (Single spray at 35 DAS)	17.76	42.45	80.17	85.37	255	7.48
50% of RDN & 100% PK + 2 sprays of Nano Urea at (35 DAS) and (60-65DAS) @ 4 ml/lt water	18.23	43.09	88.29	87.62	308	7.89
SEm±	0.0152	0.245	0.773	1.031	0.337	0.072
CD (P=0.05)	0.46	0.745	2.344	3.129	1.02	0.219

*RDF, Recommended dose of fertilizers, *RDN, Recommended dose of nitrogen, *DAS, Days after sowing

Table 2 Effect of nano-urea-based nitrogen management on yield attributing characters of wheat

Treatments	Grains per Spike	Test wt. (gm)/ 1000 grains wt.	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})
Farmers Practice (RDF: 100:40:20) kg/ha	26.41	34.38	33.14	51.70
50% of RDN & 100% PK + nano urea @4ml/lt. water (Single spray at 35 DAS)	27.63	35.94	34.02	52.92
50% of RDN & 100% PK + 2 sprays of Nano Urea at (35 DAS) and (60-65DAS) @ 4 ml/lt water	29.43	36.70	34.54	53.60
SEm±	0.135	0.136	0.193	0.959
CD (P=0.05)	0.410	0.412	0.587	2.909

*RDF, Recommended dose of fertilizers, *RDN, Recommended dose of nitrogen, *DAS, Days after sowing

Table 3 Effect of nano-urea-based nitrogen management on post harvest soil of wheat

Treatments	pH	EC (dS^{-m})	OC (%)	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	S (mg kg^{-1})	Zn (mg kg^{-1})
Initial Soil	6.89	0.12	0.35	111	13	113	9	0.14
Farmers Practice (RDF: 100:40:20) kg ha^{-1}	7.52	0.17	0.36	172.63	20.25	137.88	7.81	0.15
50% of RDN & 100% PK + nano urea @4ml/lt. water (Single spray at 35 DAS)	7.88	0.21	0.38	177.38	23.00	147.00	8.17	0.23
50% of RDN & 100% PK + 2 sprays of Nano Urea at (35 DAS) and (60-65DAS) @ 4 ml/lt water	8.21	0.17	0.41	179.25	23.75	157.88	8.84	0.23
SEm±	0.19	0.022	0.005	0.90	0.520	0.475	0.105	0.009
CD (P=0.05)	NS	NS	0.015	2.731	1.579	1.439	0.318	0.028

*RDF, Recommended dose of fertilizers, *RDN, Recommended dose of nitrogen, *DAS, Days after sowing

Table 4 Effect of nano-urea-based nitrogen management on economics of wheat

Treatments	Grain Yield (q ha^{-1})	Cost of cultivation (₹ ha^{-1})	Gross Return (₹ ha^{-1})	Net Return (₹ ha^{-1})	B:C Ratio
Farmers Practice (RDF: 100:40:20) kg ha^{-1}	33.14	34108	86960	52852	2.54
50% of RDN & 100% PK + nano urea @4ml/lt. water (Single spray at 35 DAS)	34.02	34792	89208	54416	2.56
50% of RDN & 100% PK + 2 sprays of Nano Urea at (35 DAS) and (60-65DAS) @ 4 ml/lt water	34.54	34921	90520	55599	2.59

*RDF, Recommended dose of fertilizers, *RDN, Recommended dose of nitrogen, *DAS, Days after sowing

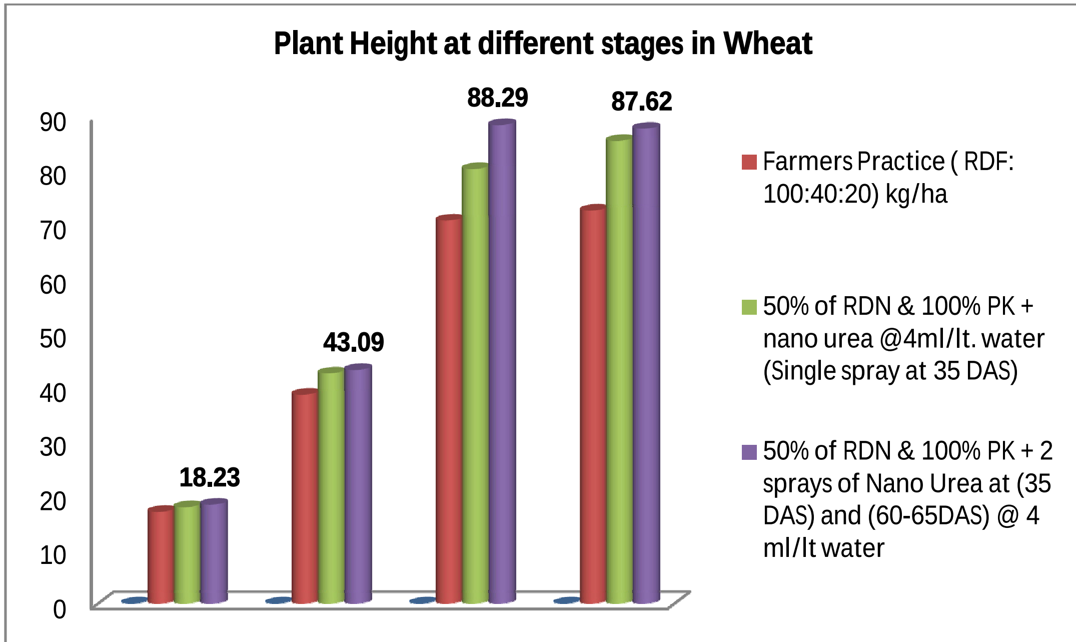

Fig. 1. Effect of nano urea on plant height (cm) in wheat

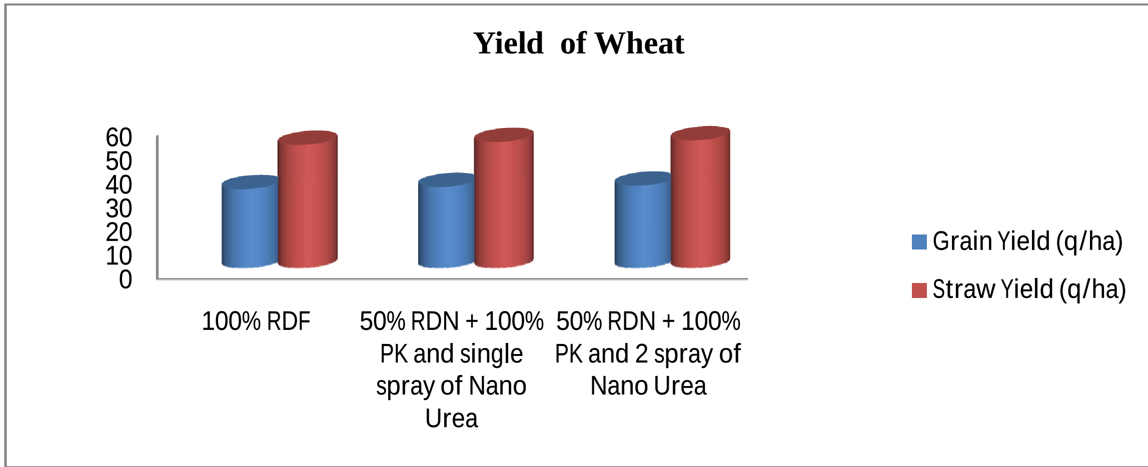

Fig. 2. Effect of nano urea on grain and straw yield of wheat

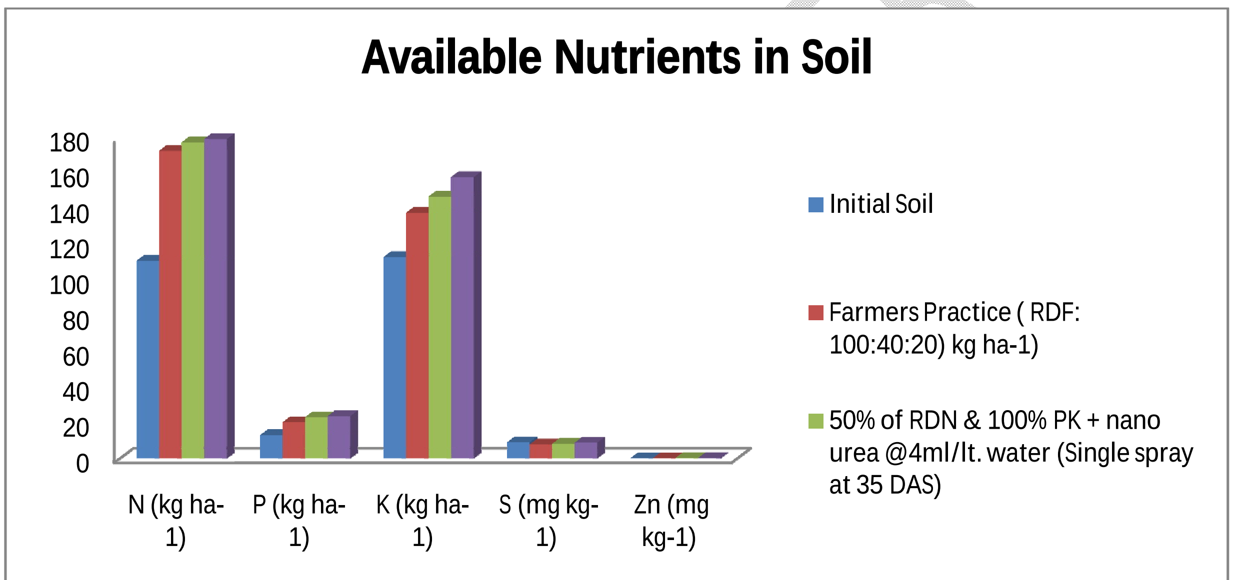

Fig. 3. Effect of nano urea on available nutrients in soil

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