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Effect of Different Nitrogen Levels and Nano Urea on Yield and Economics of Wheat under Mid Hills of Himachal Pradesh, India

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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

Optimizing nitrogen levels, particularly through nano-urea application, significantly enhances wheat yield by improving nutrient uptake efficiency, leading to increased economic returns while minimizing environmental impact. A field experiment was conducted at Chamelti Agriculture Farm, Shoolini University of Biotechnology and Management Sciences, Solan during *rabi* season of 2023-

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24 to study the effect of different nitrogen levels and nano urea on yield and economics of wheat under mid hills of Himachal Pradesh. The field experiment was laid out in Split plot design consisting of four treatments in main plot and three treatments in sub plot. The treatments of main plot were comprising of four nitrogen levels *viz.,* Control, 50% RDN, 75% RDN and 100% RDN (recommended dose of nitrogen) and three foliar spray of Nano urea in sub plot *viz.,* at CRI stage, Tillering stage and Jointing stage. The recommended doses of fertilizers were applied in each plot. Phosphorous and potassium were applied as basal at the time of sowing through SSP and MOP. Nitrogen was applied in two split doses, half dose was applied through urea at the time of sowing as basal dose and remaining half dose was applied in two equal splits at the time of CRI and tillering stage. While, foliar application of nano urea was applied as per treatment @ 3 ml l^{-1} of water. Other operations were performed as per package of practices of this area. The results revealed that application of 100% RDN recorded significantly higher yield and economics. While, Foliar spray of nano urea at jointing stage resulted in significantly higher yield and economics of wheat *viz.,* grain yield (kg ha^{-1}), straw yield (kg ha^{-1}), biological yield (kg ha^{-1}), gross returns (₹ ha^{-1}) and net returns (₹ ha^{-1}).

Keywords: Wheat; nitrogen levels; foliar application; nano urea; tillering.

1. INTRODUCTION

Wheat (*Triticum aestivum*. L) known as “king of cereals” belongs to family “Poaceae” and originated from South-West Asia. Wheat is also the world’s most produced and consumed food crop which is being utilized by billions of people (Pathak and Shrivastav, 2015). It is one of the most important *rabi* season crop in India, covering about 50% total area under food crops and producing more than 70% of total food grain among *rabi* season crops. It is one of the most nutritive food grain crops, containing 60-68% carbohydrates, 8-15% protein, 1.5-2% fat, 2-3% sugar, 2-2.5% cellulose and 1.5-2% minerals (Singh *et al*., 2011). Wheat is high in amino acids like niacin and thiamine. Its high gluten content contributes to the structural framework of the spongy cellular structure of bread, chapati, and other baked items (Shewry *et al*., 2002).

Increasing wheat production is challenging due to climatic fluctuations, poor soil health and increased risk of diseases and insect infestations. To deal with these challenges, innovative technologies with the potential to increase the sustainability of current cropping systems must be included in modern agriculture. Among these technological advances, nanotechnology is gaining attention because of its wide range of application in agriculture. It is used for the development of numerous precise e-tools, including nano fertilizers, nano pesticides and nano herbicides (Jasrotia *et al*., 2018, Jyoti Bala et al, 2024).

Nano urea has claimed to satisfy these goals by being a sound financial and economic investment. Because of numerous elements like the expanding population, soil nutrient depletion, limited land resources and climate change, more environmentally friendly and efficient inputs are required. Additionally, conventional fertilizers have an appallingly low nutrient use efficiency. According to reports between 40-70% of the nitrogen in applied fertilizer is lost to the environment and does not reach the plant, which results in large financial losses. We must use new agricultural inputs that produce more with less harm in order to combat this. One such resource that can be applies is nano-fertilizer. Traditional fertilizers are adapted into nano-fertilizers, which are based on nanotechnology (Ojha *et al*., 2023).

Nano urea has high nitrogen efficiency and is environmentally friendly. This fertilizer is known as "smart fertilizer" as it reduces. Nitrous oxide emission are primarily responsible for polluting soil, air and water bodies. It also helps to reduce global warming. These properties make it a promising alternative to conventional urea (Kannoj *et al*., 2022).

2. MATERIALS AND METHODS

The field experiment was conducted during *rabi* season of 2023-24 at Chamelti Agriculture Farm, (latitude 30º 85’67.30 N and longitude 77º 13’20.38 E.). MS Swaminathan School of Agriculture, Shoolini University of Biotechnology and Management Sciences, Solan (H.P.).

The experiment was laid in split plot design with three replications. There were 12 treatment combinations consisting of four nitrogen levels

(Control, 50% RDN (Recommended Dose of Nitrogen), 75% RDN and 100% RDN) in main plot and three foliar sprays of nano urea (CRI stage (Crown Root Initiation), Tillering stage and Jointing stage) in sub plot. The soil of experimental field was sandy loam in texture, medium organic carbon, available nitrogen and potassium, high in phosphorous and neutral in reaction with EC in safer range. Recommended dose of N, P and K (120:60:30 kg ha^{-1}) was applied as per treatment. Full doses of phosphorous and potassium were applied as basal at the time of sowing through SSP (Single Super Phosphate) and MOP (Muriate of Potash). While, nitrogen was applied in two split doses, half dose was applied at the time of sowing as basal dose and remaining half dose was applied in two equal splits at the time of CRI and tillering stage. Foliar application of nano urea was applied as per treatment @ 3 ml l^{-1} of water. The crop was sown on 3rd November 2023 with row to row spacing of 20 cm. The total rainfall received during the crop season (November to May, 2023-24) was 209 mm. Observations were recorded as per standard procedure. Statistical analysis in Split Plot Design according to the method of Gomez and Gomez (1984). The critical difference was calculated to assess the significance of treatment mean wherever the 'F' test was found significant at a 5 percent level.

3. RESULTS

3.1 Effect on Yield

3.1.1 Grain yield (kg ha^{-1})

Table 1 indicate that among the different nitrogen levels, significantly higher grain yield of wheat (2573 kg ha^{-1}) was recorded with the application of (N_4) 100% RDN which was statistically at par with (N_3) 75% RDN i.e., 2491 kg ha^{-1}. While, least grain yield (1764 kg ha^{-1}) was recorded under the treatment (N_1) Control.

In case of foliar spray of nano urea, significantly higher grain yield (2501 kg ha^{-1}) was recorded with the application of (F_2) Foliar spray of nano urea at tillering stage which was statistically at par with the (F_3) Foliar spray of nano urea at jointing stage i.e., 2382 kg ha^{-1}. While, least grain yield (1903 kg ha^{-1}) was recorded under (F_1) Foliar spray of nano urea at CRI stage.

3.1.2 Straw yield (kg ha^{-1})

Significantly higher straw yield of wheat (4410 kg ha^{-1}) was recorded with the application of (N_4) 100% RDN which was statistically at par with (N_3) 75% RDN i.e., 4325 kg ha^{-1}. While, least straw yield (3378 kg ha^{-1}) was recorded under (N_1) Control (Table 1).

Among the foliar spray of nano urea, significantly higher straw yield (4366 kg ha^{-1}) was recorded with the application of (F_2) Foliar spray of nano urea at tillering stage which was statistically at par with (F_3) Foliar spray of nano urea at jointing stage i.e., 4255 kg ha^{-1}. While, least straw yield (3500 kg ha^{-1}) was recorded under (F_1) Foliar spray of nano urea at CRI stage.

3.1.3 Biological yield (kg ha^{-1})

The application of (N_4) 100% RDN recorded the significantly higher biological yield (Table 1) of wheat (6982 kg ha^{-1}) which was statistically at par with (N_3) 75% RDN i.e., 6816 kg ha^{-1}. While, least biological yield (5142 kg ha^{-1}) was recorded under (N_1) Control.

In case of foliar spray of nano urea, significantly higher biological yield (6867 kg ha^{-1}) was recorded with the treatment (F_2) Foliar spray of nano urea at tillering stage which was statistically at par with (F_3) Foliar spray of nano urea at jointing stage i.e., 6637 kg ha^{-1}. While, least biological yield (5403 kg ha^{-1}) was recorded under (F_1) Foliar spray of nano urea at CRI stage.

3.1.4 Harvest index (%)

Harvest index of wheat does not reach the level of significance (Table 1). However, the maximum harvest index (36.87 %) was recorded with the application of (N_4) 100% RDN. While, least harvest index (34.59 %) was recorded under (N_1) Control.

In case of foliar spray of nano urea, the maximum harvest index (36.25 %) was recorded with the application of (F_2) Foliar spray of nano urea at tillering stage. While, the least harvest index (35.45 %) was recorded under (F_1) Foliar spray of nano urea at CRI stage.

3.2 Economics

3.2.1 Cost of cultivation (₹ ha^{-1})

Cost of cultivation was higher with the application of (N_4) 100% RDN i.e., ₹ 36311 ha^{-1}. While, least cost of cultivation (₹ 34767 ha^{-1}) was recoded under (N_1) Control (Table 2).

Table 1. Effect of nitrogen levels and nano urea on yield (kg ha^{-1}) of wheat

Treatments	Yield (Kg ha^{-1})			Harvest index (%)
	Grain yield	Straw yield	Biological yield	
Nitrogen Levels				
N_1: Control	1764	3378	5142	34.59
N_2: 50% RDN	2220	4049	6269	35.46
N_3: 75% RDN	2491	4325	6816	36.44
N_4: 100% RDN	2573	4410	6982	36.87
SEm±	**52**	**127**	**147**	**0.83**
LSD (*p*=0.05)	**179**	**439**	**507**	**NS**
Foliar spray of Nano Urea				
F_1: CRI stage	1903	3500	5403	35.45
F_2: Tillering stage	2501	4366	6867	36.25
F_3: Jointing stage	2382	4255	6637	35.82
SEm±	**42**	**82**	**120**	**0.77**
LSD (*p*=0.05)	**126**	**245**	**360**	**NS**
Interaction (N x F)	**NS**	**NS**	**NS**	**NS**

Table 2. Effect of nitrogen levels and nano urea on economics (₹ ha^{-1}) of wheat

Treatments	Economics (₹ ha^{-1})			B:C ratio
	Cost of cultivation	Gross returns	Net returns	
Nitrogen Levels				
N_1: Control	34767	57617	22850	0.66
N_2: 50% RDN	35539	71690	36151	1.02
N_3: 75% RDN	35925	79576	43650	1.22
N_4: 100% RDN	36311	81951	45640	1.26
SEm±	**-**	**1525**	**1525**	**0.04**
LSD (*p*=0.05)	**-**	**5277**	**5277**	**0.13**
Foliar spray of Nano Urea				
F_1: CRI stage	35636	61573	25938	0.72
F_2: Tillering stage	35636	79543	43907	1.23
F_3: Jointing stage	35636	77009	41374	1.16
SEm±	**-**	**1166**	**1166**	**0.03**
LSD (*p*=0.05)	**-**	**3495**	**3495**	**0.10**
Interaction (N x F)	-	NS	NS	NS

Among the foliar spray of nano urea, cost of cultivation was same among all the treatments i.e., ₹ 35636 ha^{-1}.

3.2.2 Gross returns (₹ ha^{-1})

In case of different nitrogen levels (Table 2), significantly higher gross returns (₹ 8195 ha^{-1}) was recorded with the application of (N_4) 100% RDN which was statistically at par with (N_3) 75% RDN i.e., ₹ 79576 ha^{-1}. While, the least gross returns (₹ 57617 ha^{-1}) was recorded under (N_1) Control.

Among the foliar spray of nano urea, significantly higher gross returns (₹ 79543 ha^{-1}) was recorded with the application of (F_2) Foliar spray of nano urea at tillering stage which was statistically at par with (F_3) Foliar spray of nano urea at jointing stage i.e., ₹ 77009 ha^{-1}. While, least gross returns (₹ 61573 ha^{-1}) were recorded under (F_1) Foliar spray of nano urea at CRI stage.

3.2.3 Net returns (₹ ha^{-1})

Application of (N_4) 100% RDN recorded the significantly higher net returns (₹ 45640 ha^{-1}) which was statistically at par with (N_3) 75% RDN i.e., ₹ 43650 ha^{-1}. While least net returns (₹ 22850 ha^{-1}) were recorded under (N_1) Control (Table 2).

In case of the foliar spray of nano urea, significantly higher net returns (₹ 43907 ha^{-1}) were recorded with the application of (N_4) 100% RDN (F_2) Foliar spray of nano urea at tillering

stage which was statistically at par with (F_3) Foliar spray of nano urea at jointing stage i.e., ₹ 41374 ha^{-1}. While least net returns (₹ 25938 ha^{-1}) was recorded under (F_1) Foliar spray of nano urea at CRI stage.

3.2.4 B:C ratio

Among the different nitrogen levels, significantly higher B:C ratio (1.26) was recorded with the application of (N_4) 100% RDN which was statistically at par with (N_3) 75% RDN i.e., 1.22. While, least B:C ratio 0.66 was recorded under (N_1) Control (Table 2).

In case of the foliar spray of nano urea, significantly higher B:C ratio (1.23) was recorded with the application of (F_2) Foliar spray of nano urea at tillering stage which was statistically at par with (F_3) Foliar spray of nano urea at jointing stage i.e., 1.16. While, least B:C ratio (0.72) was recorded under (F_1) Foliar spray of nano urea at CRI stage.

4. DISCUSSION

4.1 Effect of Nitrogen Levels on Yield

A close examination of the data (Table 1) under different nitrogen levels revealed that significantly higher yield (grain, straw and biological) was observed with the application of (N_4) 100% RDN which was statistically at par with (N_3) 75% RDN. It might be due to that yield of crop is result of different yield attributes like number of effective tillers, spike length, grains $spike^{-1}$ which directly influenced the grain and straw yield. Higher the yield attributes higher the yield. Nitrogen influences biomass synthesis and use sun energy for productivity of the plant which enhance the yield and yield contributing parameters. Similar observations were recorded by the several earlier workers in wheat Abedi *et al*. (2013), Chauhan *et al*. (2014), Sikarwar *et al*. (2022) and Ullah *et al*. (2018).

4.2 Effect of Nitrogen Levels on Economics

The data (Table 2) clearly showed that among the nitrogen levels, (N_4) 100% RDN recorded significantly higher gross returns, net returns and B:C ratio which was statistically at par with the (N_3) 75% RDN. It might be due to the higher grain and straw yield said in above treatments. Similar findings were observed by Kamble and Todmal (2020).

4.3 Effect of Foliar Spray of Nano Urea on Yield

The data (Table 1) showed significantly higher yield (grain, straw and biological) was recorded with the application of (F_2) Foliar spray of nano urea at tillering stage which was statistically at par with (F_3) Foliar spray of nano urea at jointing stage. It might be due to the size of one nano urea particle is 30 nm which is very small from the stomatal opening of leaves. Due to its small size and unique surface properties, liquid nano urea is absorbed more effectively by plants when sprayed on their leaves which improves yield of crop. Similar findings were found by Chudasama *et al*. (2024), Gangwar *et al*. (2022).

4.4 Effect of Foliar Spray of Nano Urea on Economics

The data (Table 2) showed significantly higher gross returns, net returns and B:C ratio was recorded with the application of (F_2) Foliar spray of nano urea at tillering stage which was statistically at par with (F_3) Foliar spray of nano urea at jointing stage. It might be due to nano urea improves crop growth, yield characteristics as well as source-sink interactions and active photosynthetic activities, all of which have direct impact on output. Lower cultivation costs made it possible by reduced urea treatment and effective foliar nano fertilizer application. This boosted grain and straw yield and eventually higher net returns. Similar findings were observed by Kumar *et al*. (2020), Mehta and Bharat (2017).

5. CONCLUSION

On the basis of one year experiment it is to be concluded that application of 100% RDN along with foliar spray of nano urea at tillering stage @ 3 ml l^{-1} of water exerted significant improvement in yield and economics of wheat under mid hills of Himachal Pradesh.

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 the writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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