E-ISSN: 2618-0618
P-ISSN: 2618-060X

www.agronomyjournals.com
2024; SP-7(8): 623-628
Received: 11-06-2024
Accepted: 17-07-2024

Jyoti Bala
Department of Agronomy, MS Swaminathan School of Agriculture, Shoolini University of Biotechnology and Management Sciences, Solan, Himachal Pradesh, India

Kartikeya Choudhary
Department of Agronomy, MS Swaminathan School of Agriculture, Shoolini University of Biotechnology and Management Sciences, Solan, Himachal Pradesh, India

Ranjeet Singh Bochalya
Department of Agronomy, MS Swaminathan School of Agriculture, Shoolini University of Biotechnology and Management Sciences, Solan, Himachal Pradesh, India

Himanshu
Department of Agronomy, MS Swaminathan School of Agriculture, Shoolini University of Biotechnology and Management Sciences, Solan, Himachal Pradesh, India

Corresponding Author:
Jyoti Bala
Department of Agronomy, MS Swaminathan School of Agriculture, Shoolini University of Biotechnology and Management Sciences, Solan, Himachal Pradesh, India

Effect of different nitrogen levels and nano urea on growth and yield attributes of wheat under mid hills of Himachal Pradesh

Jyoti Bala, Kartikeya Choudhary, Ranjeet Singh Bochalya and Himanshu

DOI: https://doi.org/10.33545/2618060X.2024.v7.i8Sh.1338

Abstract
The current experiment was conducted at Chamelti Agriculture Farm, Shoolini University, Solan during *rabi* season of 2023-24 to study the effect of different nitrogen levels and nano urea on growth and yield attributes of wheat under mid hills of Himachal Pradesh. 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. 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.*, CRI stage, Tillering stage and Jointing stage. The recommended doses of fertilizers were applied in each plot. The doses of 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 crop growth characters and yield attributes *viz*., plant height (cm), number of tillers (m^{-2}), chlorophyll content, dry matter accumulation (g m^{-2}), crop growth rate (g m^{-2} day^{-1}), number of effective tillers (m^{-2}) and number of grains $spike^{-1}$. While, foliar spray of nano urea at jointing stage resulted in significantly higher plant height and chlorophyll content. However, Foliar spray of nano urea at tillering stage resulted in significantly higher number of tillers, dry matter accumulation, crop growth rate, number of effective tillers, number of grains $spike^{-1}$. Spike length (cm) and test weight (g) was higher with the application of 100% RDN and nano urea at tillering stage but the difference was found to be non-significant.

Keywords: Wheat, Nitrogen levels, foliar application, Nano urea and tillering

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) [1]. 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. Wheat 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) [2]. 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) [3].
The world production of wheat is 770.4 million tonnes. China is the largest producer of wheat in the world and India is the second largest producer of wheat in the word. The other leading producers of wheat include Russia and United States of America (FAOSTAT, 2022) [4]. In India, wheat is grown over an area of 30.47 million hectares with total production of 106.84 million tonnes with the average productivity of 3507 kg ha^{-1} (Agricultural Statistics at Glance, 2022) [5]. Major wheat growing states of India are Uttar Pradesh, Punjab, Haryana, Rajasthan, Bihar, Gujarat, M.P., Maharashtra, West Bengal, Uttarakhand and Himachal Pradesh.

In Himachal Pradesh, it is grown over an area of 33,148 hectares with total production of 570,378 metric tonnes with the average productivity of 1710 kg ha^{-1}. Meanwhile, in Solan district, wheat is grown over an area of 24,521 hectares with total production of 58,053 metric tonnes with the average productivity of 2370 kg ha^{-1} (Statistical Abstract of Himachal Pradesh, 2021-22).

Unbalanced and overuse of fertilizers had negative effect on nutrient availability to plants as well as soil fertility and soil health. It also caused nutrient losses from the fields through leaching and gases emission which have been leading environmental pollution. In India, the total consumption, production and import of nitrogen as a fertilizer is 191.01, 136.85 and 51.91 lakh tonnes, respectively (Pocket Book of Agricultural Statistics, 2020) [7]. The most common used fertilizer for nitrogen application is urea. To overcome all these problems nanotechnology introduced the nano fertilizers with small particle size less than 100 nm. Foliar application of nano fertilizers like, nano urea increases NUE and nutritional quality of crops through bio-fortification and cause low salt accumulation in soil (Kumar *et al*., 2021) [8].

Liquid nano urea developed by Indian Farmers' Fertilizer Cooperative Limited (IFFCO) as a substitute for urea to meet the nitrogen requirement of plants, especially during critical growth stages. Used as a foliar spray, it helps effectively absorb and penetrate nitrogen into the leaves and reaches the parts of the plant where nitrogen is needed and releases nutrients in a controlled manner, reducing loss to the environment. In addition, it improves the physiological properties of the crop, especially under drought stress conditions. Due to its large surface area, better solubility and smaller size, nano urea can help in various metabolic reactions resulting in improved yield and quality parameters and reduced fertilizer (Lakshman *et al*., 2022) [9].

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, 75% RDN and 100% RDN) in main plot and three foliar sprays of nano urea (CRI stage, 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 and MOP. 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.

Results

Effect on crop growth characters

Plant height (cm): The data revealed that the application of (N_4) 100% RDN was recorded significantly higher plant height (21.70 cm) of wheat at 30 DAS which was statistically at par with (N_3) 75% RDN i.e., 20.72 cm. Same trend was also observed at 60, 90, 120, 150 DAS and at harvest.

Among the foliar spray of Nano urea, significantly higher plant height (20.97 cm) of wheat at 30 DAS was recorded with (F_1) Foliar spray of nano urea at CRI stage. Whereas, at 60 DAS significantly higher plant height (27.49 cm) of wheat was recorded with (F_2) Foliar spray of nano urea at tillering stage which was statistically at par with (F_1) Foliar spray of nano urea at CRI stage i.e., 25.93 cm. However, at 90 DAS significantly higher plant height (50.21 cm) was recorded with the application of (F_3) Foliar spray of nano urea at jointing stage which was statistically at par with (F_2) Foliar spray of nano urea at tillering stage i.e., 46.65 cm. Same trend was observed at 120, 150 DAS and at harvest.

Number of tillers (m^{-2}): At 60 DAS, significantly higher number of tillers (210.66 m^{-2}) were recorded with application of (N_4) 100% RDN which was statistically at par with (N_3) 75% RDN i.e., 207.74 m^{-2}. Same trend was observed at 90, 120, 150 DAS and at harvest.

In case of foliar spray of Nano urea, significantly higher number of tillers (207.33 m^{-2}) were recorded with the application of (F_2) Foliar spray of nano urea at tillering stage at 60 DAS which was statistically at par with (F_3) Foliar spray of nano urea at jointing stage i.e., 201.53 m^{-2}. Same trend was observed at 90, 120, 150 DAS and at harvest.

Chlorophyll content (SPAD value): Among the different nitrogen levels, significantly higher chlorophyll content of wheat (36.86) was recorded with application of (N_4) 100% RDN, which was statistically at par with (N_3) 75% RDN i.e., 35.04. Same trend was observed at 60, 90, 120 and 150 DAS.

Application of Foliar spray of nano urea at CRI stage, significantly increase the chlorophyll content
(37.05) at 30 DAS. Whereas, at 60 DAS significantly higher chlorophyll content 39.95 was recorded with application of (F_2) Foliar spray of nano urea at tillering stage which was statistically at par with (F_1) Foliar spray of nano urea at CRI stage i.e., 37.58. At 90 DAS significantly higher SPAD value (48.62) was recorded with the application of (F_3) Foliar spray of nano urea at jointing stage which was statistically at par with (F_2) Foliar spray of nano urea at tillering stage i.e., 45.91. Same trend was observed at 120 and 150 DAS.

Dry matter accumulation (g m^{-2}): In case of different nitrogen levels, significantly higher dry matter accumulation (72.22 g m^{-2}) was recorded with the application of (N_4) 100% RDN at 30 DAS, which was statistically at par with (N_3) 75% RDN i.e., 71.20 g m^{-2}. Same trend was observed at 60, 90, 120, 150 DAS and at harvest.

Among the foliar spray of nano urea, significantly higher dry matter accumulation (69.89 g m^{-2}) was recorded with application of (F_1) foliar spray of nano urea at CRI stage at 30 DAS. Whereas, at 60 DAS significantly higher dry matter accumulation (149.99 g m^{-2}) 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., 147.83 g m^{-2}. Same trend was observed at 90, 120, 150 and at harvest.

Crop growth rate (g m^{-2} day^{-1})

Among the nitrogen levels, significantly higher crop growth rate (2.41 g m^{-2} day^{-1}) was recorded with application of (N_4) 100% RDN which was statistically at par with (N_3) 75% RDN i.e., 2.37 g m^{-2} day^{-1}. Same trend was observed at 60, 90, 120, 150 DAS and at harvest during course of study.

Application of (F_1) Foliar spray of nano urea at CRI stage at 30 DAS, recorded significantly higher crop growth rate (2.33 g m^{-2} day^{-1}). Whereas, at 60 DAS significantly higher crop growth rate (2.95 g m^{-2} day^{-1}) was recorded with the foliar 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., 2.85 g m^{-2} day^{-1}. Same trend was observed at 90, 120, 150 DAS and at harvest.

Yield attributes

Number of effective tillers (m^{-2}): Application of (N_4) 100% RDN recorded significantly higher number of effective tillers (200.42 m^{-2}) which was statistically at par with (N_3) 75% RDN i.e., 196.42 m^{-2}.

Among the foliar spray of nano urea, significantly higher number of effective tillers (193.99 m^{-2}) was recorded with 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., 189.06 m^{-2}.

Number of grains $spike^{-1}$: Number of grains $spike^{-1}$ was recorded significantly higher (46.76) with the application of (N_4) 100% RDN which was statistically at par with (N_3) 75% RDN i.e., 43.80.

In case of foliar spray of nano urea, significantly higher number of grains $spike^{-1}$ (42.78) was recorded with 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., 41.87.

Spike length (cm): Spike length of wheat does not reach the level of significance, however the maximum spike length (15.24 cm) was recorded with the application of (N_4) 100% RDN and least spike length (14.59 cm) was recorded under (N_1) Control.

Among the foliar spray of nano urea, the maximum spike length (15.07 cm) was recorded with the application of (F_2) Foliar spray of nano urea at tillering stage, while least spike length (14.77 cm) was recorded under the treatment (F_1) Foliar spray of nano urea at CRI stage.

Test weight (g): Test weight does not reach the level of significance, however the maximum test weight (41.13 g) was recorded with the application of (N_4) 100% RDN and least test weight (39.58 g) was recorded under (N_1) Control.

In case of foliar spray of nano urea, the maximum test weight (41.11 g) was recorded with application of (F_2) Foliar spray of nano urea at tillering stage and least test weight (39.21 g) was recorded under (F_1) Foliar spray of nano urea at CRI stage.

Discussion

Effect of nitrogen levels on crop growth characters

Significantly higher plant height, chlorophyll content (SPAD value), number of tillers (m^{-2}), dry matter accumulation (g m^{-2}) and crop growth rate (g m^{-2} day^{-1}) were recorded with the application of (N_4) 100% RDN over the rest of treatments which was statistically at par with (N_3) 75% RDN. This might be due to the fact that nitrogen plays an important role in cell division and cell elongation which results in increase in internodal length and thus growth in the term of height. Application of nitrogenous fertilizers increases the cytokinin content within tiller nodes and further enhance the germination of tiller which increases the tiller population. Cytokinins are nitrogen containing purines and pyrimidines that promote the development of buds and tillers in plants. Another possible explanation for rise tillers along with the improvement in nitrogen rate is to the process by which the carbohydrates are converted to protein, increasing the number of expanding cells, which ultimately results in more tillers. Nitrogen has high effect of leaf growth of plant because it increases the leaf area which influences the photosynthesis and leads to higher chlorophyll content in leaves. Dry matter accumulation rate significantly higher due to the increased photosynthetic rate and higher leaf area that increased total dry matter production. Nitrogen application promotes regular growth and development of wheat as well as healthy tiller development. Increased nitrogen dosage may also have contributed to an increase in the generation of total dry matter because it raises the rate of photosynthetic activity and the area of leaves. Physiological parameters namely plant height, number of tillers increased with increase in nitrogen doses. Increasing nitrogen doses also led to significantly increase in chlorophyll content, dry matter accumulation and crop growth rate. Similar results were found by different workers Kaur *et al*. (2015) [11], Patra and Ray (2018) [12], Gupta *et al*. (2023) [13], Bojovic and Markovic (2009) [15] and Liu *et al.* (2011) [16].

Effect of nitrogen levels on yield attributes

Significantly higher value of yield attributes like no. of grains $spike^{-1}$ and number of effective tillers (m^{-2}) were recorded with application of (N_4) 100% RDN over the rest of the treatments which was statistically at par with (N_3) 75% RDN. This might be due to increasing nitrogen levels led to increase in number of effective tillers, grains $spike^{-1}$. Nitrogen enhances the photosynthesis process and translocate the photosynthate to grain which results in higher yield attributes. Nitrogen was supplied from early vegetative growth to flowering, synchronizing crop needs and producing the desired results. The maximum number of fertile tillers in the later stages of the crop, nitrogen is still available, which may have led to the highest possible number of grains $spike^{-1}$. Similar results were found by Kousar *et al*. (2015) [17], Yousaf *et al*. (2014) [18].

Effect foliar spray of nano urea on crop growth characters

A significantly increase in plant height and chlorophyll content (SPAD value) was recorded with the application of (F_3) Foliar spray of nano urea at jointing stage which was statistically at par with the (F_2) Foliar spray of nano urea at tillering stage. Whereas, number of tillers (m^{-2}), dry matter accumulation and crop growth rate were recorded significantly higher with 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. This might be due to nitrogen applied through nano urea acts as a primary component of amino acids, proteins, vitamins, hormones and enzymes. All of which have an immediate effect in promoting cell division and enlargement both longitudinally and transversely which increased meristematic activities leads to an increase in internodal length resulting in an increased plant height. Nitrogen plays a role in many physiological functions of plant growth and development. These functions include the synthesis of chlorophyll and the development of thylakoid and chloroplasts thus leading to higher chlorophyll content.

Nano urea enhance the activity of chloroplast antioxidant enzyme system and nitrate reductase which are potential mechanisms that enhanced growth and resulted in higher number of tillers. Nano urea helped in larger leaf surface area and enabled greater utilization of solar radiation and available nutrients which is crucial for expanding the photosynthetic surface area. This in turn could have resulted in enhanced accumulation and translocate of photosynthates, ultimately boosting biomass production. Nano urea also provide nutrients for the plant or aid in the transport or absorption of available nutrients resulting in better crop growth rate. Similar findings were observed by the several workers Singh *et al*. (2017) [19], Kandil and Eman (2017) [20], Mahil and Kumar (2019) [21], Rathnayaka *et al*. (2018) [22], Kumar *et al*. (2020) [23], Bayu *et al*. (2005) [24] and Rostaman *et al*. (2021) [25].

Effect of foliar spray of nano urea on yield attributes

Significantly higher yield attributes like number of grains spike^{-1} and number of effective tillers was recorded with 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. This might be due to nano fertilizers increase in biological reactions, enzymatic reactions and the regularity of hormones which has created a new opportunity for plant to accumulate the required dry material for pollination and fertilization which leads to increase the number of grains spike^{-1}. Nano urea enhanced the optimal growth of plant parts and metabolic process such as photosynthesis which translates to higher photosynthates accumulation and translocation to the economically important plant parts resulting in increased number of reproductive tillers. Similar findings were observed by Rani *et al*. (2019) [26] and Benzon *et al*. (2015) [27].

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 growth and yield attributes of wheat under mid hills of Himachal Pradesh.

Table 1: Effect of nitrogen levels and nano urea on plant height (cm) of wheat at periodic intervals

Treatments	Plant height (cm)					
	30 DAS	60 DAS	90 DAS	120 DAS	150 DAS	At harvest
Nitrogen Levels						
N_1: Control	15.72	18.20	34.69	61.51	60.61	59.18
N_2: 50% RDN	19.87	24.12	43.65	71.77	68.47	66.16
N_3: 75% RDN	20.72	28.11	52.14	83.06	82.26	80.63
N_4: 100% RDN	21.70	30.50	56.01	87.78	86.36	84.14
SEm±	0.59	0.82	1.48	2.42	2.40	2.28
LSD (*p*=0.05)	2.04	2.85	5.13	8.38	8.32	7.87
Foliar spray of Nano Urea						
F_1: CRI stage	20.97	25.93	43.01	70.62	69.07	68.69
F_2: Tillering stage	18.79	27.49	46.65	76.46	74.82	73.46
F_3: Jointing stage	18.75	22.28	50.21	81.01	79.38	75.43
SEm±	0.50	0.67	1.24	1.79	1.77	1.75
LSD (*p*=0.05)	1.49	2.02	3.72	5.38	5.31	5.26
Interaction (N x F)	NS	NS	NS	NS	NS	NS

Table 2: Effect of nitrogen levels and nano urea on number of tillers (m^{-2}) of wheat at periodic intervals

Treatments	No. of tillers (m^{-2})				
	60 DAS	90 DAS	120 DAS	150 DAS	At harvest
Nitrogen Levels					
N_1: Control	188.57	209.58	238.91	236.98	234.02
N_2: 50% RDN	195.64	218.31	249.51	247.49	243.31
N_3: 75% RDN	207.74	231.19	264.22	261.27	257.08
N_4: 100% RDN	210.66	236.57	271.99	270.89	267.46
SEm±	3.74	4.96	6.00	4.77	4.38
LSD (*p*=0.05)	12.96	17.18	20.77	16.50	15.16
Foliar spray of Nano Urea					
F_1: CRI stage	193.11	215.30	246.30	246.05	242.13
F_2: Tillering stage	207.33	231.58	265.24	261.49	257.33
F_3: Jointing stage	201.53	224.86	256.94	254.94	251.94
SEm±	3.15	3.94	4.77	3.75	3.68
LSD (*p*=0.05)	9.44	11.80	14.31	11.24	11.03
Interaction (N x F)	NS	NS	NS	NS	NS

Table 3: Effect of nitrogen levels and nano urea on chlorophyll content (SPAD value) of wheat at periodic intervals

Treatments	Chlorophyll content (SPAD value)				
	30 DAS	60 DAS	90 DAS	120 DAS	150 DAS
Nitrogen Levels					
N_1: Control	26.76	30.18	36.14	40.44	39.64
N_2: 50% RDN	32.32	36.34	42.89	47.11	45.52
N_3: 75% RDN	35.04	40.35	49.04	54.72	52.31
N_4: 100% RDN	37.05	44.14	54.15	60.93	59.17

SEm±	0.74	1.15	1.28	1.42	1.27
LSD (*p*=0.05)	2.55	3.98	4.41	4.91	4.39
Foliar spray of Nano Urea					
F_1: CRI stage	34.26	37.58	42.14	48.32	46.81
F_2: Tillering stage	32.06	39.95	45.91	51.17	49.29
F_3: Jointing stage	32.06	35.74	48.62	52.91	51.39
SEm±	0.56	0.93	0.95	1.00	0.98
LSD (*p*=0.05)	1.67	2.80	2.85	3.00	2.93
Interaction (N x F)	NS	NS	NS	NS	NS

Table 4: Effect of nitrogen levels and nano urea on dry matter accumulation (g m^{-2}) of wheat at periodic intervals

Treatments	Dry matter accumulation (g m^{-2})					
	30 DAS	60 DAS	90 DAS	120 DAS	150 DAS	At harvest
Nitrogen Levels						
N_1: Control	50.68	105.79	185.24	340.28	415.13	437.1
N_2: 50% RDN	65.01	145.37	231.71	388.26	495.68	532.9
N_3: 75% RDN	71.20	159.72	250.10	411.84	520.89	579.4
N_4: 100% RDN	72.22	165.41	257.68	420.58	530.82	593.5
SEm±	2.00	3.61	6.33	9.16	10.11	12.5
LSD (*p*=0.05)	6.91	12.48	21.90	31.69	34.98	43.1
Foliar spray of Nano Urea						
F_1: CRI stage	69.89	134.40	180.79	335.37	426.35	459.3
F_2: Tillering stage	62.22	149.99	257.79	422.09	531.06	583.7
F_3: Jointing stage	62.21	147.83	254.97	413.26	514.48	564.2
SEm±	1.66	2.67	5.45	6.77	7.19	10.2
LSD (*p*=0.05)	4.98	8.02	16.33	20.30	21.55	30.6
Interaction (N x F)	NS	NS	NS	NS	NS	NS

Table 5: Effect of nitrogen levels and nano urea on crop growth rate (g m^{-2} day^{-1}) of wheat at periodic intervals

Treatments	Crop growth rate (g m^{-2} day^{-1})					
	0-30 DAS	30 -60 DAS	60-90 DAS	90-120 DAS	120-150 DAS	150 DAS- at harvest
Nitrogen Levels						
N_1: Control	1.69	1.84	2.65	5.17	2.50	0.73
N_2: 50% RDN	2.17	2.68	2.88	5.22	3.58	1.24
N_3: 75% RDN	2.37	2.95	3.01	5.39	3.63	1.95
N_4: 100% RDN	2.41	3.11	3.08	5.43	3.67	2.09
SEm±	0.06	0.08	0.09	0.13	0.10	0.05
LSD (*p*=0.05)	0.20	0.26	0.29	0.40	0.32	0.15
Foliar spray of Nano Urea						
F_1: CRI stage	2.33	2.15	1.55	5.15	3.03	1.10
F_2: Tillering stage	2.07	2.93	3.59	5.48	3.63	1.75
F_3:Jointing stage	2.07	2.85	3.57	5.28	3.37	1.66
SEm±	0.05	0.07	0.08	0.11	0.09	0.03
LSD (*p*=0.05)	0.17	0.21	0.24	0.35	0.28	0.11
Interaction (N x F)	NS	NS	NS	NS	NS	NS

Table 6: Effect of nitrogen levels and nano urea on yield attributes of wheat at harvest

Treatments	Yield attributes			
	No. of effective tillers (m^{-2})	No. of grains $spike^{-1}$	Spike length (cm)	Test weight (g)
Nitrogen Levels				
N_1: Control	171.18	32.51	14.59	39.58
N_2: 50% RDN	185.56	40.47	14.67	40.00
N_3: 75% RDN	196.42	43.80	14.99	40.10
N_4: 100% RDN	200.42	46.76	15.24	41.13
SEm±	3.91	1.21	0.26	0.87
LSD (*p*=0.05)	13.52	4.20	NS	NS
Foliar spray of Nano Urea				
F_1: CRI stage	182.14	38.01	14.77	39.21
F_2: Tillering stage	193.99	42.78	15.07	41.11
F_3: Jointing stage	189.06	41.87	14.78	40.29
SEm±	2.78	0.76	0.22	0.59
LSD (*p*=0.05)	8.34	2.27	NS	NS
Interaction (N x F)	NS	NS	NS	NS

References

1. Pathak V, Shrivastav S. Biochemical studies on wheat (*Triticum aestivum* L.). J Pharmacogn Phytochem. 2015;4(3):171-5.

2. Singh CM, Sharma PK, Kishor P, Mishra PK, Singh AP, Verma R, Raha P. Impact of integrated nutrient management on growth, yield and nutrient uptake by wheat (*Triticum aestivum* L.). Asian J Agric Res. 2011;5(1):76-82.
3. Shewry PR, Halford NG, Belton PS, Tatham AS. The structure and properties of gluten: an elastic protein from wheat grain. Philos Trans R Soc Lond B Biol Sci. 2002;357(1418):133-42.
4. Food and Agriculture Organization. FAOSTAT [Internet]. Rome: Food and Agriculture Organization; 2022 [cited 2024 Aug 26]. Available from: https://www.fao.org/faostat
5. Department of Agriculture and Farmer Welfare. Agricultural Statistics at a Glance. New Delhi: Department of Agriculture and Farmer Welfare; 2022. p. 48.
6. Department of Economics and Statistics, Government of Himachal Pradesh. Statistical Abstract of Himachal Pradesh 2021-22. Shimla: Department of Economics and Statistics; 2022. p. 40.
7. Government of India, Ministry of Agriculture & Farmers Welfare. Pocket Book of Agricultural Statistics. New Delhi: Directorate of Economics & Statistics; 2020.
8. Kumar Y, Tiwari KN, Singh T, Raliya R. Nanofertilizers and their role in sustainable agriculture. Ann Plant Soil Res. 2021;23(3):238-55.
9. Lakshman K, Chandrakala M, Prasad PS, Babu GP, Srinivas T, Naik NR, *et al*. Liquid nano-urea: an emerging nano fertilizer substitute for conventional urea. Chron Bioresour Manag. 2022;6(2):54-9.
10. Gomez KA, Gomez AA. Statistical Procedures for Agricultural Research. 2nd ed. New York: Wiley; 1984. p. 199-201.
11. Kaur G, Asthir B, Bains NS. Nitrogen levels effect on wheat nitrogen use efficiency and yield under field conditions. Afr J Agric Res. 2015;10(23):2372-7.
12. Patra B, Ray P. Response of wheat to various nitrogen levels under late sown condition. J Exp Agric Int. 2018;7(1):1-5.
13. Gupta V, Gupta M, Kour S, Bharat R. Growth analysis in relation to sowing environments and nitrogen levels in wheat varieties under irrigated conditions of NW Himalayas of Jammu and Kashmir. Indian J Ecol. 2023;50(2):338-44.
14. Rawate D, Patel JR, Agrawal AP, Agrawal HP, Pandey D, Patel CR, *et al*. Effect of nano urea on productivity of wheat (*Triticum aestivum* L.) under irrigated condition. Pharm Innov. 2022;11:1279-82.
15. Bojovic B, Markovic A. Correlation between nitrogen and chlorophyll content in wheat (*Triticum aestivum* L.). Kragujevac J Sci. 2009;31(5827):69-74.
16. Liu Y, Ding Y, Wang Q, Meng D, Wang S. Effects of nitrogen and 6-benzylaminopurine on rice tiller bud growth and changes in endogenous hormones and nitrogen. Crop Sci. 2011;51(2):786-92.
17. Kousar P, Ali L, Raza A, Maqbool A, Maqbool S, Rasheed S, *et al*. Effect of different levels of nitrogen on the economic yield of wheat (*Triticum aestivum* L.) variety Aas 11. Int J Agron Agric Res. 2015;6(3):7-11.
18. Yousaf M, Fahad S, Shah AN, Shaaban M, Khan MJ, Sabiel SA, *et al*. The effect of nitrogen application rates and timings of first irrigation on wheat growth and yield. Int J Agric Innov Res. 2014;2(4):645-55.
19. Singh MD. Nano-fertilizers: a new way to increase nutrient use efficiency in crop production. Int J Agric Sci. 2017;9(7):0975-3710.
20. Kandil EE, Marie EA, Marie EA. Response of some wheat cultivars to nano-, mineral fertilizers and amino acids foliar application. Alex Sci Exch J. 2017;38(1):53-68.
21. Mahil EI, Kumar BA. Foliar application of nanofertilizers in agricultural crops – a review. J Farm Sci. 2019;32(3):239-49.
22. Rathnayaka RM, Mahendran S, Iqbal YB, Rifnas LM. Influence of urea and nano nitrogen fertilizers on the growth and yield of rice (*Oryza sativa* L.) cultivar Bg 250. Int J Res Publ. 2018;3:1-10.
23. Kumar Y, Tiwari KN, Nayak RK, Rai A, Singh SP, Singh AN, *et al*. Nanofertilizers for increasing nutrient use efficiency, yield and economic returns in important winter season crops of Uttar Pradesh. Indian J Fertilisers. 2020;16(8):772-86.
24. Bayu W, Rethman NF, Hammes PS, Alemu G. Effects of farmyard manure and inorganic fertilizers on sorghum growth, yield, and nitrogen use in a semi-arid area of Ethiopia. J Plant Nutr. 2006;29(2):391-407.
25. Rostaman T, Wibowo H. The effects of nano inorganic fertilizer application on rice (*Oryza sativa* L.) productivity. In: IOP Conference Series: Earth and Environmental Science. 2021;648(1):012197. IOP Publishing.
26. Rani B, Zalawadia NM, Buha D, Rushang K. Effect of different levels of chemical and nano nitrogenous fertilizers on content and uptake of N, P, K by sorghum crop cv. Gundari. J Pharmacogn Phytochem. 2019;8(5):454-8.
27. Benzon HR, Rubenecia MR, Ultra Jr VU, Lee SC. Nano-fertilizer affects the growth, development, and chemical properties of rice. Int J Agron Agric Res. 2015;7(1):105-17.