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Effect of urea and nano urea on the content and uptake of nutrients by wheat (*Triticum aestivum* L.) under calcareous soil

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Abstract

An experiment was conducted at Wheat Research Station, Junagadh Agricultural University, Junagadh to study the effect of urea and nano urea on the content and uptake of nutrients by wheat (*Triticum aestivum* L.) under calcareous soil during the *Rabi* season of 2023-24 and 2024-25. Among the different treatments of urea and nano urea with recommended dose of fertilizer, significantly the highest N content (%) in straw at 60, 90 DAS, at harvest and grain, K content (%) in grain, N, P, K, S and Micronutrient uptake by grain and straw were observed with treatment 75% RDN through urea + 1 foliar spray of nano urea @ 6 ml/lit at 20 DAS (T₅), which maintained statistical equivalence with 75% RDN through urea + 1 foliar spray of nano urea @ 4 ml/lit at 20 DAS (T₄). While other nutrients like, P and K content (%) in straw at 60, 90 DAS, at harvest and P content (%) in grain, S, Fe, Mn, Zn and Cu content (%) in grain and straw were remain unaffected.

Keywords: Wheat, nutrients, urea, nano urea, content and uptake

Introduction

Wheat (*Triticum aestivum* L.) a vital cereal crop is classified under the family "Poaceae" and the genus "Triticum." It is a self-fertilizing plant with a chromosome complement of (2n = 42). Often referred to as the monarch of cereal crops approximately 95% of wheat cultivated worldwide is hexa ploid bread wheat (*Triticum aestivum* L.) also known as common bread wheat, while the remaining 5% consists of tetra ploid durum wheat. Wheat constitutes 30% of the global cereal food production and serves as a fundamental food source for nearly 10 billion individuals across 43 countries. It supplies roughly 20% of the world's dietary calories and 55% of all carbohydrates.

Nano fertilizers are fertilizers that contain nutrients in nano-porous materials (measuring 10⁻⁹ m) that are either supplied in particle or emulsion forms with nano dimensions or covered with a thin polymer coating. These fertilizers have the ability to distribute nutrients within plants in a targeted manner, reducing waste and delaying chemical changes. While synthetic fertilizers usually release their nutrients in 4–10 days, nano fertilizers can release their nutrients over a period of 40–50 days. Because of leaching and volatilization, a synthetic urea fertilizer can rapidly lose more than 70% of its nitrogen content after application, leaving less than 20% that is easily absorbed by plants.

To address the different challenges, nano technology presents a promising a venue. It offers arrange of applications throughout the production, processing, storage, packaging and transport of agricultural goods (Scott and Chen, 2013) ^[13]. Nano fertilizers play a crucial role in agriculture's production phase potentially bolstering sustainable soil health and crop yield. By using nano fertilizers instead of traditional ones nutrients are delivered to plants in a gradual and controlled way.

Materials and Methods

The experimental soil was clayey in texture and neutral in reaction with pH 7.80, EC 0.41 dS/m, medium in available nitrogen 259 kg/ha, low in available phosphorus 26.00 kg/ha and medium

in available potassium 257 kg/ha, low in available sulphur 9.00 mg/kg, medium in iron 7.40 mg/kg, high in manganese 10.5 mg/kg, medium in zinc 0.60 mg/kg, high in copper 1.63 mg/kg. The experiment consists of 11 treatments to evaluate combinations of RDF with nano urea in wheat (var. GJW-463). Eleven treatments comprising of absolute control (T₁), 0% RDN + 100% RDF of P & K (T₂), 75% RDN through urea + 1 foliar spray of nano urea @ 2 ml/lit at 20 DAS (T₃), 75% RDN through urea + 1 foliar spray of nano urea @ 4 ml/lit at 20 DAS (T₄), 75% RDN through urea + 1 foliar spray of nano urea @ 6 ml/lit at 20 DAS (T₅), 50% RDN through urea + 2 foliar spray of nano urea @ 2 ml/lit at 20 and 40 DAS (T₆), 50% RDN through urea + 2 foliar spray of nano urea @ 4 ml/lit at 20 and 40 DAS (T₇), 50% RDN through urea + 2 foliar spray of nano urea @ 6 ml/lit at 20 and 40 DAS (T₈), 4 foliar spray of nano urea @ 2 ml/lit at 20, 40, 50 and 60 DAS (T₉), 75% RDN through urea + 1 foliar spray of 2% urea at 20 DAS (T₁₀), 50% RDN through urea + 2 foliar spray of 2% urea at 20 and 40 DAS (T₁₁) in randomized block design with three replications. Standard agronomic practices were adopted for raising healthy crop. In this study Nitrogen content (%) in grain and straw was determined by Micro Kjeldahl method (A.O.A.C., 1965), Phosphorus content (%) was determined by the vanado-molybdo phosphoric acid method (Jackson, 1974) [3], Potassium content (%) of di-acid digested plant sample was determined using flame photometer (Jackson, 1974) [3]. Sulphur content (%) of diacid digested plant sample was determined using turbidimetry (Williams and Steinberg 1959) [19]. Micronutrient content of diacid digested plant sample was determined using Atomic Absorption Spectro photometry (Lindsay and Norwell 1978) [6]. Nutrient uptake by grain and straw were obtained by multiplication of nutrient content with grain and straw yield, respectively and divided by 100.

$$\text{NPK uptake by grain (kg/ha)} = \frac{\text{NPK content in grain (\%)} \times \text{grain yield (kg/ha)}}{100}$$

$$\text{NPK uptake by straw (kg/ha)} = \frac{\text{NPK content in straw (\%)} \times \text{straw yield (kg/ha)}}{100}$$

Results and Discussion

Effect of different treatments of urea and nano urea on the nutrient content of wheat

The data presented in Table-1 revealed that the application of 75% RDN through urea + 1 foliar spray of nano urea @ 6 ml/lit at 20 DAS (T₅) recorded significantly highest N content in straw 0.760%, 0.779% and 0.770% during 2023-24, 2024-25 and pooled results at 60 DAS, 0.570%, 0.583% and 0.577% during 2023-24, 2024-25 and pooled result at 90 DAS, 0.500%, 0.496% and 0.498% during 2023-24, 2024-25 and pooled results, respectively. N content in grain 2.04%, 2.10% and 2.07% during 2023-24, 2024-25 and pooled result. It was remains at par with T₃, T₄, T₈ and T₁₀ during 2023-24 at 60 DAS, T₃, T₄ and T₁₀ during 2024-25 at 60 DAS as well as T₃ and T₄ during pooled result at 60 DAS. It also remains at par with T₄ during both year as well as pooled results at 90 DAS and at harvest. Treatment (T₄) also remains at par with T₅ during both the year. The significantly highest K content (%) in grain 0.410%, 0.421% and 0.415% was found with treatment 75% RDN through urea + 1 foliar spray of nano urea @ 6 ml/lit at 20 DAS (T₅), followed by T₄ during both year (Table 3). While other nutrient content like P content in grain and straw, K content in straw as well as S, Fe, Mn, Zn and Cu content in grain and straw were remain unaffected (Table 2, 3, 4, 5 and 6).

Effect of different treatments of urea and nano urea on the nutrient uptake of wheat

Data presented in Table 7 and 8 indicated that the significantly highest N uptake by wheat straw 34.93, 35.37 and 35.15 kg/ha, N uptake by grain 96.82, 99.80 and 98.31 kg/ha, P uptake by straw 7.85, 7.70 and 7.71 kg/ha as well as P uptake by grain 18.63, 19.49 and 19.06 kg/ha, K uptake by straw 75.46, 76.35 and 75.90 kg/ha, K uptake by grain 20.86, 21.50 and 21.18 kg/ha, S uptake by straw 9.36, 9.40 and 9.38 kg/ha and S uptake by grain 15.69, 15.12 and 15.40 kg/ha were recorded with treatment 75% RDN through urea + 1 foliar spray of nano urea @ 6 ml/lit at 20 DAS (T₅) during both the experimental year as well as pooled results, respectively. It remains statistically at par with T₄.

Treatment 75% RDN through urea + 1 foliar spray of nano urea @ 6 ml/lit at 20 DAS (T₅) gave significantly highest Fe uptake by wheat straw 2476.91, 2501.87 and 2489.39 g/ha, Fe uptake by grain 894.29, 906.85 and 900.57 g/ha, Mn uptake by straw 679.15, 669.14 and 674.14 g/ha, Mn uptake by grain 397.46, 407.43 and 402.45 g/ha, Zn uptake by straw 554.62, 551.48 and 553.05 g/ha, Zn uptake by grain 258.80, 259.16 and 258.98 g/ha, Cu uptake by straw 102.15, 101.95 and 102.05 g/ha Cu uptake by grain 71.76, 76.83 and 74.29 g/ha, respectively during both the experimental year as well as pooled results, respectively. It remains statistically at par with T₄ (Table 9 and 10).

The significant improvement in nutrient content and uptake in wheat under combined application of conventional urea and nano urea can be attributed to enhanced nitrogen use efficiency (NUE) and improved nutrient delivery mechanisms. Nano urea, due to its extremely small particle size and high surface area, enables efficient foliar absorption through stomatal openings and cuticular pathways, resulting in rapid entry and effective translocation of nitrogen within plant tissues. In contrast to conventional urea, which suffers substantial nitrogen losses through volatilization, leaching, and denitrification, nano urea ensures a slow and controlled release of nitrogen. This controlled availability synchronizes better with crop demand during critical growth stages, particularly during grain development, thereby enhancing nitrogen assimilation and its subsequent translocation from source (leaves) to sink (grains).

Moreover, adequate nitrogen availability promotes chlorophyll synthesis, enzymatic activity, and photosynthetic efficiency, leading to higher biomass production. Since nutrient uptake is a function of both nutrient concentration and dry matter yield, increased biomass directly contributes to greater uptake of macro- and micronutrients (N, P, K, S, Fe, Zn, Mn, and Cu). Additionally, the integration of reduced basal nitrogen (75% RDN) with foliar nano urea application helps maintain nutrient balance in the soil-plant system, avoiding excessive nitrogen losses while ensuring sufficient availability. This balanced nutrition enhances root activity, nutrient mobility, and overall physiological efficiency of the plant, ultimately resulting in higher nutrient accumulation and uptake.

The process by which plants use their roots to take up vital components from the soil or surrounding environment is known as nutrient absorption. In order to support a variety of metabolic processes and maintain plant growth and development, this process entails the active or passive movement of nutrients across root cell membranes, made possible by specific transport proteins. Nutrient uptake is mostly estimated by multiplying the crop's dry matter by the nutrient concentration.

Nano urea enhances nitrogen uptake efficiency due to its nano-sized particles, which improve foliar absorption and translocation (Subramanian and Sharmila Rahale, 2021) [17]. The

superiority of T₅ could be attributed to better nitrogen utilization efficiency and balanced assimilation, whereas T₄ possibly led to saturation of uptake sites or induced metabolic imbalances. The higher nitrogen availability from soil coupled with enhanced foliar absorption of nano urea likely maximized nitrogen efficiency, as also reported by Mahajan *et al.* (2022) ^[7], Patel *et al.*, (2022) ^[8], Sharma *et al.* (2022) ^[15], Sharma *et al.* (2021) ^[14]

in pearl millet, Barkha rani *et al.* (2019) ^[11] in sorghum, Hemdan *et al.* (2020) ^[2] in lupine plant, Kanno *et al.* (2022) ^[4] in black wheat, Singh *et al.* (2023) ^[16] in wheat, Sarwar *et al.* (2021) ^[12] in sweet corn and Chavan *et al.* (2023) ^[1] in little millet, Ramirez-Rodriguez *et al.* (2020) ^[10] in wheat, Rajesh *et al.* (2021) ^[9] in sweet corn, Kumar *et al.* (2023) ^[5] in wheat, Upadhyay *et al.* (2023) ^[18] in maize.

Table 1: Effect of urea and nano urea on N content (%) in wheat straw at 60, 90 DAS, at harvest and in grain

Treatments	N content in straw (%)									N content in grain (%)		
	At 60 DAS			At 90 DAS			At harvest					
	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled
T ₁	0.630	0.637	0.634	0.424	0.420	0.422	0.320	0.348	0.334	1.51	1.48	1.50
T ₂	0.660	0.647	0.653	0.432	0.428	0.430	0.337	0.359	0.348	1.55	1.52	1.54
T ₃	0.734	0.742	0.738	0.514	0.539	0.526	0.462	0.470	0.466	1.90	1.84	1.87
T ₄	0.753	0.758	0.756	0.538	0.562	0.550	0.473	0.488	0.481	1.93	1.96	1.94
T ₅	0.760	0.779	0.770	0.570	0.583	0.577	0.500	0.496	0.498	2.04	2.10	2.07
T ₆	0.693	0.676	0.685	0.440	0.436	0.438	0.425	0.432	0.429	1.72	1.69	1.71
T ₇	0.707	0.683	0.695	0.445	0.452	0.448	0.438	0.445	0.441	1.73	1.76	1.75
T ₈	0.710	0.721	0.716	0.454	0.465	0.460	0.453	0.446	0.450	1.77	1.81	1.79
T ₉	0.673	0.663	0.668	0.434	0.427	0.431	0.407	0.395	0.401	1.57	1.59	1.58
T ₁₀	0.717	0.733	0.725	0.504	0.520	0.512	0.459	0.452	0.456	1.79	1.83	1.81
T ₁₁	0.687	0.671	0.679	0.438	0.430	0.434	0.408	0.403	0.405	1.64	1.66	1.65
S.Em.±	0.018	0.018	0.013	0.015	0.016	0.011	0.011	0.012	0.008	0.04	0.05	0.03
C.D. at 5%	0.052	0.053	0.036	0.043	0.047	0.031	0.033	0.035	0.023	0.13	0.14	0.09
C.V.%	4.36	4.39	4.37	5.32	5.79	5.56	4.58	4.75	4.66	4.45	4.71	4.58
Y												
S.Em.±	0.005			0.004			0.003			0.01		
C.D. at 5%	NS			NS			NS			NS		
YXT												
S.Em.±	0.018			0.015			0.012			0.05		
C.D. at 5%	NS			NS			NS			NS		

Table 2: Effect of urea and nano urea on P content (%) in wheat straw at 60, 90 DAS, at harvest and in grain

Treatments	P content in straw (%)									P content in grain (%)		
	At 60 DAS			At 90 DAS			At harvest					
	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled
T ₁	0.140	0.144	0.142	0.123	0.122	0.123	0.098	0.100	0.099	0.365	0.359	0.362
T ₂	0.144	0.145	0.145	0.125	0.125	0.125	0.099	0.101	0.100	0.369	0.378	0.374
T ₃	0.154	0.151	0.153	0.132	0.131	0.132	0.105	0.107	0.106	0.389	0.387	0.388
T ₄	0.155	0.151	0.153	0.133	0.132	0.133	0.111	0.108	0.110	0.390	0.395	0.393
T ₅	0.159	0.155	0.157	0.134	0.136	0.135	0.112	0.109	0.111	0.397	0.406	0.402
T ₆	0.147	0.148	0.148	0.128	0.128	0.128	0.101	0.103	0.102	0.377	0.380	0.379
T ₇	0.149	0.148	0.148	0.129	0.128	0.129	0.102	0.104	0.103	0.385	0.381	0.383
T ₈	0.151	0.149	0.150	0.130	0.130	0.130	0.103	0.105	0.104	0.387	0.384	0.385
T ₉	0.145	0.146	0.146	0.126	0.125	0.125	0.099	0.101	0.100	0.373	0.381	0.377
T ₁₀	0.154	0.150	0.152	0.131	0.131	0.131	0.104	0.106	0.105	0.388	0.385	0.387
T ₁₁	0.146	0.147	0.147	0.127	0.126	0.127	0.100	0.102	0.101	0.374	0.382	0.378
S.Em.±	0.005	0.004	0.003	0.004	0.004	0.003	0.004	0.003	0.003	0.011	0.010	0.007
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C.V.%	5.21	5.06	5.13	4.72	5.09	4.91	6.90	5.54	6.25	4.81	4.66	4.73
Y												
S.Em.±	0.001			0.002			0.001			0.003		
C.D. at 5%	NS			NS			NS			NS		
YXT												
S.Em.±	0.004			0.006			0.004			0.010		
C.D. at 5%	NS			NS			NS			NS		

Table 3: Effect of urea and nano urea on K content (%) in wheat straw at 60, 90 DAS, at harvest and in grain

Treatments	K content in straw (%)									K content in grain (%)		
	At 60 DAS			At 90 DAS			At harvest					
	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled
T ₁	1.500	1.509	1.504	1.250	1.259	1.254	0.973	0.963	0.968	0.293	0.300	0.297
T ₂	1.525	1.510	1.517	1.275	1.260	1.267	0.975	0.968	0.972	0.300	0.313	0.307
T ₃	1.600	1.594	1.597	1.350	1.344	1.347	1.050	1.047	1.048	0.373	0.367	0.370
T ₄	1.620	1.603	1.612	1.370	1.353	1.362	1.056	1.056	1.056	0.410	0.421	0.415
T ₅	1.625	1.617	1.621	1.375	1.360	1.368	1.061	1.077	1.069	0.435	0.450	0.443
T ₆	1.545	1.558	1.551	1.295	1.308	1.301	0.995	0.990	0.992	0.330	0.317	0.323
T ₇	1.548	1.563	1.556	1.298	1.313	1.306	1.007	1.022	1.014	0.343	0.330	0.337
T ₈	1.580	1.570	1.575	1.330	1.320	1.325	1.030	1.027	1.028	0.353	0.337	0.345
T ₉	1.539	1.541	1.540	1.289	1.291	1.290	0.984	0.973	0.978	0.310	0.317	0.313
T ₁₀	1.588	1.581	1.585	1.338	1.331	1.335	1.038	1.031	1.035	0.357	0.360	0.358
T ₁₁	1.543	1.555	1.549	1.293	1.305	1.299	0.989	0.986	0.988	0.323	0.321	0.322
S.Em.±	0.040	0.042	0.030	0.042	0.040	0.032	0.030	0.040	0.030	0.012	0.012	0.008
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.034	0.035	0.024
C.V.%	4.65	4.45	4.55	5.54	5.16	5.35	5.57	6.54	6.07	5.70	5.87	5.79
Y												
S.Em.±	0.012			0.013			0.012			0.003		
C.D. at 5%	NS			NS			NS			NS		
YXT												
S.Em.±	0.041			0.045			0.036			0.012		
C.D. at 5%	NS			NS			NS			NS		

Table 4: Effect of urea and nano urea on S content (%) and Fe content (mg/kg) in wheat straw and grain

Treatments	S content in straw (%)			S content in grain (%)			Fe content in straw (mg/kg)			Fe content in grain (mg/kg)		
	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled
T ₁	0.177	0.179	0.178	0.290	0.299	0.295	323.00	325.00	324.00	171.81	170.60	171.24
T ₂	0.179	0.180	0.180	0.291	0.299	0.295	327.67	326.32	327.00	173.75	171.33	172.54
T ₃	0.189	0.186	0.188	0.310	0.314	0.312	348.00	340.00	344.00	181.67	180.33	181.00
T ₄	0.190	0.188	0.189	0.315	0.319	0.317	349.00	345.36	347.18	185.00	185.10	185.05
T ₅	0.196	0.195	0.196	0.332	0.320	0.326	351.67	353.11	352.39	187.33	190.21	188.77
T ₆	0.182	0.182	0.182	0.300	0.306	0.303	337.33	335.25	336.29	176.78	176.09	176.43
T ₇	0.184	0.183	0.183	0.304	0.308	0.306	340.00	338.33	339.17	177.56	177.31	177.43
T ₈	0.186	0.184	0.185	0.306	0.309	0.308	340.67	338.17	339.42	178.45	178.00	178.23
T ₉	0.180	0.181	0.181	0.293	0.300	0.296	329.90	330.33	330.12	175.00	173.16	174.08
T ₁₀	0.187	0.185	0.186	0.309	0.313	0.311	340.67	339.55	340.10	179.71	179.10	179.41
T ₁₁	0.181	0.182	0.182	0.298	0.302	0.300	335.00	333.00	334.00	176.43	173.67	175.05
S.Em.±	0.006	0.007	0.004	0.011	0.009	0.010	9.26	8.67	6.35	5.51	5.83	4.01
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C.V.%	5.30	5.36	5.33	5.92	4.56	5.27	4.74	4.46	4.60	5.34	5.68	5.51
Y												
S.Em.±	0.002			0.004			2.59			1.64		
C.D. at 5%	NS			NS			NS			NS		
YXT												
S.Em.±	0.006			0.010			8.97			5.67		
C.D. at 5%	NS			NS			NS			NS		

Table 5: Effect of urea and nano urea on Mn and Zn content (mg/kg) in wheat straw and grain

Treatments	Mn content (mg/kg) in straw			Mn content (mg/kg) in grain			Zn content (mg/kg) in straw			Zn content (mg/kg) in grain		
	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled
T ₁	87.55	87.21	87.38	77.50	77.08	77.29	71.33	70.67	71.00	48.77	48.85	48.81
T ₂	88.00	89.36	88.68	77.72	78.13	77.93	71.67	73.67	72.67	49.32	48.98	49.15
T ₃	95.00	93.15	94.08	82.91	83.11	83.01	77.79	77.00	77.39	51.05	51.33	51.19
T ₄	95.33	93.67	94.50	83.54	84.04	83.79	78.17	77.67	77.92	51.46	52.00	51.73
T ₅	96.88	94.03	95.46	83.67	84.15	83.91	78.79	78.33	78.56	54.50	54.21	54.36
T ₆	89.62	91.00	90.31	80.32	80.08	80.20	74.12	75.00	74.56	49.95	49.67	49.81
T ₇	90.71	91.33	91.02	81.04	81.12	81.08	74.79	75.67	75.23	50.16	49.76	49.96
T ₈	94.00	91.69	92.50	81.20	81.35	81.27	75.96	76.33	76.15	50.35	50.50	50.43
T ₉	89.00	89.42	89.21	79.94	78.64	79.29	73.10	74.00	73.55	49.33	49.27	49.30
T ₁₀	94.72	92.45	93.59	81.88	81.79	81.83	76.42	76.67	76.54	50.38	50.67	50.52
T ₁₁	89.33	89.42	89.38	80.10	79.42	79.76	73.82	75.00	74.41	49.75	49.45	49.60
S.Em.±	2.71	2.87	1.98	2.27	2.35	1.63	2.34	2.24	1.62	1.50	1.61	1.10
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C.V.%	5.12	5.46	5.29	4.86	5.04	4.95	5.40	5.13	5.27	5.16	5.55	5.36
Y												
S.Em.±	0.81			0.67			0.66			0.45		
C.D. at 5%	NS			NS			NS			NS		
YXT												
S.Em.±	2.80			2.31			2.29			1.56		
C.D. at 5%	NS			NS			NS			NS		

Table 6: Effect of urea and nano urea on Cu content (mg/kg) in wheat straw and grain

Treatments	Cu content in straw (mg/kg)			Cu content in straw (mg/kg)		
	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled
T ₁ Absolute control	13.26	13.50	13.38	14.30	14.55	14.42
T ₂ 0% RDN + 100% RDF of P & K	13.64	13.55	13.60	14.54	14.68	14.61
T ₃ 75% RDN through urea + 1 foliar spray of nano urea @ 2 ml/lit at 20 DAS	14.23	14.21	14.22	15.07	15.04	15.06
T ₄ 75% RDN through urea + 1 foliar spray of nano urea @ 4 ml/lit at 20 DAS	14.33	14.35	14.34	15.14	15.34	15.31
T ₅ 75% RDN through urea + 1 foliar spray of nano urea @ 6 ml/lit at 20 DAS	14.53	14.44	14.49	15.55	15.83	15.69
T ₆ 50% RDN through urea + 2 foliar spray of nano urea @ 2 ml/lit at 20 and 40 DAS	13.86	13.75	13.80	14.89	14.78	14.84
T ₇ 50% RDN through urea + 2 foliar spray of nano urea @ 4 ml/lit at 20 and 40 DAS	13.92	13.97	13.95	14.92	14.89	14.91
T ₈ 50% RDN through urea + 2 foliar spray of nano urea @ 6 ml/lit at 20 and 40 DAS	14.09	14.14	14.12	14.94	14.97	14.95
T ₉ 4 foliar spray of nano urea @ 2 ml/lit at 20, 40, 50 and 60 DAS	13.70	13.68	13.69	14.69	14.64	14.67
T ₁₀ 75% RDN through urea + 1 foliar spray of 2% urea at 20 DAS	14.15	14.22	14.18	14.97	15.01	14.99
T ₁₁ 50% RDN through urea + 2 foliar spray of 2% urea at 20 and 40 DAS	13.84	13.72	13.78	14.76	14.69	14.73
S.Em.±	0.37	0.41	0.27	0.39	0.45	0.30
C.D. at 5%	NS	NS	NS	NS	NS	NS
C.V.%	4.58	5.05	4.82	4.61	5.28	4.96
Y						
S.Em.±			0.11			0.12
C.D. at 5%			NS			NS
YXT						
S.Em.±			0.39			0.43
C.D. at 5%			NS			NS

Table 7: Effect of urea and nano urea on N and P uptake (kg/ha) by wheat straw and grain

Treatments	N uptake (kg/ha) by straw			N uptake (kg/ha) by grain			P uptake (kg/ha) by straw			P uptake (kg/ha) by grain		
	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled
T ₁	16.12	17.73	16.92	40.67	40.63	40.79	4.95	5.12	5.03	9.83	9.85	9.84
T ₂	17.76	18.85	18.30	50.69	50.15	50.42	5.22	5.32	5.27	12.07	12.46	12.26
T ₃	28.98	29.92	29.45	81.93	80.37	81.15	6.60	6.83	6.72	16.81	16.91	16.86
T ₄	32.98	33.88	33.43	88.90	90.91	89.90	7.76	7.48	7.62	17.98	18.36	18.17
T ₅	34.93	35.37	35.15	96.82	99.80	98.31	7.85	7.70	7.71	18.63	19.49	19.06
T ₆	24.64	25.24	24.94	69.53	68.03	68.78	5.85	6.03	5.94	15.22	15.33	15.28
T ₇	25.85	26.37	26.11	70.72	71.60	71.16	6.00	6.17	6.08	15.74	15.49	15.61
T ₈	27.13	26.51	26.82	73.70	74.45	74.08	6.19	6.26	6.22	16.10	15.82	15.96
T ₉	21.81	21.53	21.67	52.66	54.87	53.76	5.32	5.50	5.41	12.52	13.12	12.82
T ₁₀	27.56	27.23	27.40	75.17	76.72	75.95	6.24	6.39	6.32	16.34	16.16	16.25
T ₁₁	23.38	23.29	23.34	61.68	62.99	62.33	5.73	5.92	5.83	14.06	14.46	14.26
S.Em.±	1.61	2.02	1.29	3.74	3.69	2.63	0.33	0.38	0.25	0.55	1.02	0.58
C.D. at 5%	4.74	5.96	3.69	11.04	10.88	7.51	0.96	1.13	0.72	1.62	2.99	1.65
C.V.%	10.89	13.46	12.27	9.29	9.07	9.18	9.19	10.61	9.94	6.30	11.47	9.29
Y												
S.Em.±	0.53			1.07			0.10			0.24		
C.D. at 5%	NS			NS			NS			NS		
YXT												
S.Em.±	1.83			3.72			0.36			0.82		
C.D. at 5%	NS			NS			NS			NS		

Table 8: Effect of urea and nano urea on K and S uptake (kg/ha) by wheat straw and grain

Treatments	K uptake (kg/ha) by straw			K uptake (kg/ha) by grain			S uptake (kg/ha) by straw			S uptake (kg/ha) by grain		
	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled
T ₁	48.99	49.11	49.05	7.89	8.24	8.08	4.77	4.91	4.84	7.81	8.21	8.02
T ₂	51.39	50.85	51.12	9.81	10.35	10.08	5.85	5.93	5.89	9.52	9.85	9.68
T ₃	65.83	66.63	66.23	16.13	16.01	16.07	8.16	8.12	8.14	13.41	13.70	13.55
T ₄	73.59	73.34	73.47	18.89	19.54	19.21	8.74	8.72	8.73	14.51	14.82	14.66
T ₅	75.46	76.35	75.90	20.86	21.50	21.18	9.36	9.40	9.38	15.69	15.12	15.40
T ₆	57.73	57.79	57.76	13.32	12.78	13.05	7.34	7.34	7.34	12.09	12.34	12.22
T ₇	59.42	60.58	60.00	14.03	13.42	13.73	7.51	7.43	7.47	12.44	12.51	12.47
T ₈	61.71	60.94	61.32	14.71	13.87	14.29	7.74	7.60	7.67	12.74	12.73	12.74
T ₉	52.67	52.99	52.83	10.40	10.92	10.66	6.05	6.24	6.15	9.82	10.35	10.08
T ₁₀	62.35	62.11	62.23	15.01	15.12	15.06	7.87	7.76	7.81	13.00	13.16	13.08
T ₁₁	56.72	56.94	56.83	12.16	12.13	12.15	6.82	6.89	6.85	11.24	11.43	11.34
S.Em.±	4.63	3.79	2.99	1.02	0.95	0.70	0.48	0.49	0.34	0.66	0.50	0.41
C.D. at 5%	13.65	11.19	8.55	3.01	2.81	2.00	1.42	1.43	0.98	1.94	1.48	1.18
C.V.%	13.24	10.82	12.09	12.62	11.73	12.18	11.42	11.53	11.47	9.39	7.08	8.30
Y												
S.Em.±	1.22			0.29			0.14			0.17		
C.D. at 5%	NS			NS			NS			NS		
YXT												
S.Em.±	4.23			0.99			0.48			0.59		
C.D. at 5%	NS			NS			NS			NS		

Table 9: Effect of urea and nano urea on Fe and Mn uptake (g/ha) by wheat straw and grain

Treatments	Fe uptake (g/ha) by straw			Fe uptake (g/ha) by grain			Mn uptake (g/ha) by straw			Mn uptake (g/ha) by grain		
	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled
T ₁	1627.18	1657.40	1642.29	462.77	468.30	465.65	441.73	445.33	443.53	208.75	211.59	210.17
T ₂	1726.99	1715.41	1721.20	568.27	564.97	566.62	463.86	467.62	465.74	254.17	257.41	255.79
T ₃	2182.84	2163.50	2173.17	784.91	787.57	786.24	595.56	591.63	593.60	358.20	362.93	360.57
T ₄	2431.03	2401.20	2416.11	852.43	859.64	856.03	664.05	650.61	657.33	384.81	390.42	387.61
T ₅	2476.91	2501.87	2489.39	894.29	906.85	900.57	679.15	669.14	674.14	397.46	407.43	402.45
T ₆	1955.53	1957.60	1956.57	714.44	710.11	712.28	520.07	530.99	525.53	323.96	323.01	323.49
T ₇	2006.67	2006.77	2006.72	725.78	721.24	723.51	534.93	541.71	538.32	331.20	329.92	330.56
T ₈	2041.86	2011.74	2026.80	742.93	733.33	738.13	563.40	544.53	553.97	338.06	335.18	336.62
T ₉	1764.97	1800.96	1782.96	586.78	595.86	591.32	476.52	486.30	481.41	268.10	271.26	269.68
T ₁₀	2045.51	2044.48	2045.00	756.10	752.23	754.17	568.42	558.32	563.37	343.48	339.50	343.99
T ₁₁	1920.90	1927.00	1923.95	663.76	656.93	660.35	512.20	517.24	514.72	301.70	300.56	301.13
S.Em.±	134.93	108.31	86.51	44.17	40.11	29.83	34.80	38.15	25.82	18.29	22.58	14.53
C.D. at 5%	398.04	319.52	247.26	130.30	118.32	85.26	102.66	112.56	73.80	53.95	66.62	41.53
C.V.%	11.59	9.30	10.51	10.77	9.79	10.29	11.01	12.11	11.57	9.85	12.10	11.04
Y												
S.Em.±	35.32			12.18			10.54			5.93		
C.D. at 5%	NS			NS			NS			NS		
YXT												
S.Em.±	122.34			42.19			36.52			20.55		
C.D. at 5%	NS			NS			NS			NS		

Table 10: Effect of urea and nano urea on Zn and Cu uptake (g/ha) by wheat straw and grain

Treatments	Zn uptake (g/ha) by straw			Zn uptake (g/ha) by grain			Cu uptake (g/ha) by straw			Cu uptake (g/ha) by grain		
	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled
T ₁	359.33	360.33	359.83	131.36	134.09	132.73	66.76	68.85	67.81	38.52	39.94	39.21
T ₂	377.69	387.06	382.38	161.29	160.87	161.08	71.89	71.18	71.54	47.54	48.38	47.96
T ₃	487.63	489.97	488.80	220.53	224.20	222.37	89.19	90.49	89.84	65.11	65.68	65.39
T ₄	544.33	539.47	541.90	237.07	241.57	239.32	99.86	99.66	99.76	70.35	71.26	70.81
T ₅	554.62	551.48	553.05	258.80	259.16	258.98	102.15	101.95	102.05	71.76	76.83	74.29
T ₆	430.01	437.59	433.80	200.72	200.33	200.53	80.42	80.24	80.33	60.05	59.60	59.83
T ₇	441.32	448.74	445.03	204.91	202.39	203.65	82.18	82.85	82.51	60.98	60.57	60.78
T ₈	455.24	453.38	454.31	209.58	208.08	208.83	84.48	83.99	84.23	62.19	61.67	61.93
T ₉	391.32	404.09	397.71	165.41	169.88	167.65	73.33	74.55	73.94	49.28	50.52	49.90
T ₁₀	458.84	461.92	460.38	211.97	212.80	212.38	84.94	85.66	85.30	62.47	63.03	62.75
T ₁₁	423.22	433.79	428.51	187.61	187.22	187.41	79.40	79.37	79.38	55.59	55.60	55.60
S.Em.±	29.53	24.48	19.18	10.60	12.09	8.04	5.34	5.48	3.83	3.12	4.40	2.70
C.D. at 5%	87.11	72.21	54.81	31.26	35.67	22.97	15.76	16.17	10.94	9.19	12.99	7.71
C.V.%	11.43	9.39	10.45	9.15	10.40	9.80	11.13	11.35	11.24	9.15	12.76	11.12
Y												
S.Em.±	7.83			3.28			1.56			1.10		
C.D. at 5%	NS			NS			NS			NS		
YXT												
S.Em.±	27.12			11.37			5.41			3.81		
C.D. at 5%	NS			NS			NS			NS		

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