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Effect of Ni and N sources on wheat (*Triticum aestivum* L.) yield and nutrient uptake

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Abstract
Nitrogen is the most extensively limiting plant nutrient in crop production. A majority of soils in the world are mineral soils and nitrogen deficiency in mineral soils is widespread. Nickel is an essential micronutrient for normal plant growth and development and part of several biological functions. Ni being a vital element contribute significant role in nitrogen assimilation as well as helps plants against numerous biotic and abiotic stresses. Keeping these facts in view a field experiment was conducted in Rabi Season of 2018-19at the research plot of Department of Agricultural Chemistry and Soil Science, Udai Pratap (Autonomous) College, Varanasi. The experiment was carried out in Factorial Randomized Block Design (FRBD) with three replications. Treatment includes two nitrogen levels (0 and 120 kg ha^{-1}) with three nitrogen sources viz; N_{120}UR (Urea), N_{120}AS (ammonium sulphate), N_{120}CAN (calcium ammonium nitrate) and four nickel levels 0, 1, 2 and 4 kg ha^{-1} (Ni_0, Ni_1, Ni_2 and Ni_4). Ni was applied in the form of $NiCl_2.H_2O$ as per the requirement of treatment as basal dose. Important growth parameters (plant height and number of tillers) at different growth stages, dry matter yield (grain and straw) and nutrient uptake were determined. Results revealed that nitrogen and nickel supply significantly affected all the parameters under study when compared with no supply of nitrogen and nickel. The nitrogen application through urea registered the highest growth parameters, dry matter yield as well as nutrient content and their uptake by grain and straw of wheat as compared to ammonium sulphate and calcium ammonium nitrate. The nickel application @ 2 kg ha^{-1} recorded significantly maximum increase in all growth attributes as well as yield attributes. The interaction effect was found to be significant. Due to interaction effect maximum plant height, number of tillers and dry matter yield were recorded with the treatment $N_{120}URNi_2$, followed by $N_{120}AS\ Ni_2$ and $N_{120}CANNi_2$. Whereas, maximum nitrogen and nickel contents and their respective uptake were recorded with $N_{120}URNi_4$.

Keywords: Nickel, nitrogen, wheat yield, N & Ni uptake

1. Introduction

Present agricultural system depends upon mining of plant nutrients by adoption of intensive tillage, use of high yielding varieties, imbalanced use of organic and inorganic sources of plant nutrients, less recycling of crop residues into the soil, soil erosion and injudicious use of irrigation water (Singh *et al*. 2019) [23]. Fertilizer is an essential input to agriculture used by the farmers and directly affected by the crop response, fertilizer cost, price realized by farmers for their produce and the access to the fertilizer. India is the second largest producer and consumer of nitrogenous fertilizer in the world (Praveen a 2014) [18]. A majority of soils in the world are mineral soils and organic soils occupy only a small area. Nitrogen deficiency in mineral soils and crops is widespread, and nitrogen is the most extensively limiting plant nutrient in crop production. Essentiality of nickel (Ni) for higher plants was first reported by (Dixon *et al*. 1975) [5]. Nickel is an essential micronutrient for normal plant growth and development and part of several biological functions (Brown 2007) [2]. It is an integral part of several enzymes such as glyoxalase-1 and urease required for nitrogen metabolism in higher plants (Mustafiz *et al*. 2014) [14]. Wheat is staple food crop of India. It is used in different purposes namely source of carbohydrate, protein and raw materials for different food manufacturing industries. 90% Indian soils are deficient in nitrogen, wheat crop requires high rate of nitrogenous fertilizers. Among the nitrogenous fertilizer sources, the farmers utilize urea as nitrogen source than other sources like, ammonium sulphate, calcium ammonium nitrate etc. due to its high tolerance of plants to the ionic form of nitrogen. Keeping these facts in view, present experiment was carried out to observe the significance of nitrogen source and nickel supply for wheat crop.

2. Materials and Methods

A field experiment was conducted in Rabi Season of 2018-19 at the research plot of Department of Agricultural Chemistry and Soil Science, Udai Pratap (Autonomous) College, Varanasi. The experiment was carried out in Factorial Randomized Block Design (FRBD) with three replications. Treatment includes two nitrogen levels (0 and 120 kg ha^{-1}) with three nitrogen sources viz; N_{120}UR (Urea), N_{120}AS (ammonium sulphate), N_{120}CAN (calcium ammonium nitrate) and four nickel levels 0, 1, 2 and 4 kg ha^{-1} (Ni_0, Ni_1, Ni_2 and Ni_4). Ni was applied in the form of $NiCl_2.H_2O$ as per the requirement of treatment as basal dose. Recommended doses of P and K (60:60 kg ha^{-1}) were applied as basal dose. The wheat variety HUW-234 used as test crop. The crop was irrigated thrice in different interval. Intercultural operations were done as recommended practice or as when required. Response of wheat to applied treatments were evaluated in the form of growth parameters (plant height and number of tillers) at different growth stages, dry matter yield (grain and straw) and nutrient uptake. The organic carbon of the soil samples was estimated by Walkley and Black's wet chromic acid digestion method (1934) [26]. The pH and electrical conductivity (EC) of soil were determined in a soil water suspension (1:2.5) with the help of glass electrode pH and TDS meter. The plant available N, P and K were determined by alkaline potassium permanganate method (Subbiah and Asija, 1956) [24], Olsen's method (Olsen *et al.*, 1954) [15] and 1*N*ammonium acetate extract with the help of flame photometer (Jackson, 1973) [11], respectively. Total nitrogen was determined by colorimetric method as described by Tandon (1993) [25]. P and K from grain and straw samples of wheat were analyzed using 2:5 perchloric acid:nitric acid extract. Total phosphorus was determined by vanadomolybdophosphoric acid yellow colour method (Tondon, 1993) [25]. Total potassium was determined flame-photometrically (Jackson, 1973) [11]. Nickel was determined by using DTPA extract by AAS method. The important initial soil characteristics of the experimental soil were as pH, 8.23, E.C, 0.27dS m^{-1} and organic carbon 0.37%.Available N, P, K (kg ha^{-1}) and Ni (ppm) were 244.00, 14.50, 186.00 and 0.002, respectively.

3. Results and Discussion

3.1 Growth attributes

The data presented in table 1 on the effect of levels and sources of nitrogen and nickel on plant height of wheat at 45 DAS indicated that plant height of wheat was significantly affected by different levels nickel and sources of nitrogen. Plant height at 45 days after sowing (DAS)was recorded significantly higher (34.80 cm)with the application of urea at 120 kg N ha^{-1} over the other sources, ammonium sulphate (33.39 cm) and calcium ammonium nitrate (32.87 cm). The maximum plant height at 45 DAS due to Ni application was recorded in the treatment applied at 2 kg ha^{-1}(35.75 cm) over the other doses of nickel. The interaction effect was found significant and plant height at 45 DAS recorded significantly maximum (41.00 cm) with combined effect of Ni at 2 kg ha^{-1} and urea application. The data on plant height at harvest of wheat crop have been presented in table 2. The similar result was recorded at harvest as in case of 45 DAS regarding height. The significantly highest plant height at harvest of wheat was recorded with the application of 120 kg ha^{-1}nitrogen through urea (93.86 cm) as compared to ammonium sulphate (92.72 cm) and calcium ammonium nitrate (91.57 cm). The maximum plant height was observed at harvest due to Ni application at 2 kg ha^{-1} (92.64 cm) over the other doses of Ni. The interaction was also found to be significant in terms of plant height and maximum was with Ni @ 2 kg ha^{-1}with urea application. Table 3 and 4 shows the significant effect of levels and sources of nitrogen and nickel on number of tillers per plant of wheat at 45 days after showing (DAS) and at harvest stage of wheat crop. The maximum number of tillers per plant (6.24) as illustrated in table 3 at 45 days after sowing (DAS) was recorded significantly higher in the treatment supplied with nitrogen @120 kg ha^{-1} through urea over the other sources of nitrogen. In case of nickel application the maximum tiller count was observed at 45 DAS due to application of 2 kg ha^{-1} of nickel compared to the other doses (0 and 1 kg ha^{-1}) of nickel. The interaction effect was also found to be significant regarding number of tillers per plant at 45 DAS and at harvest (table 3 and 4). Highest tiller count (8.15 and 11.50) was in treatment combination of 120 kg N ha^{-1} supplied with urea and 2 kg ha^{-1} of nickel. The possible mechanism improving plant growth and development could be involvement of Ni which is required for optimum functioning of enzymes such as urease and hydrogenase metabolism Harish *et al.* (2008) [10]. As Ni is closely associated with N-urea assimilation, growth promotion in plants fertilized with Ni can also be attributed to enhanced Ni-urea assimilation. The stimulating effect of a moderate Ni supply in urea grown plants is well documented in wide range of plants (Gerendas and Sattelmacher, 1997) [7].The findings are also in accordance with the results obtained by (Gheibi *et al.* 2011) [9] who reported that both plant growth and leaf chlorophyll content of the urea fed plants increased significantly with the increase in nickel content up to a certain level. They further reported that the plants received urea plus nickel gave better response than those that received ammonium nitrate plus nickel. Increase in chlorophyll content due to nickel application is also documented by (Lavres *et al.* 2016) [12]. Dalton *et al.* (1988) [4] stated that Ni enhances the urease activity in plants. Urease plays an essential role in mobilization of nitrogenous compounds in plants, a process that is especially important during seed germination and fruit formation when protein reserves are degraded into amino acids. Arginine, an abundant amino acid in plants when degraded, produces urea as a product and urease is needed for utilization. The increase in growth may also be due to increased chlorophyll content which ultimately increases the photosynthesis.

3.2 Dry Matter Yield

Application of N through various sources as well as Ni significantly influenced the dry matter yield at 45 DAS (table 5) and found highest with the application of urea at 120 kg N ha^{-1}. Whereas with the increasing levels of Ni application (Ni 2 kg ha^{-1}), increment in dry matter (12.24q ha^{-1}) of the wheat plant was observed. Due to interaction effect significantly maximum dry matter (14.20 q ha^{-1}) of plant was found with combined application of Ni at 2 kg ha^{-1} and urea application at 120 kg N ha^{-1}. Application of N using urea, ammonium sulphate and calcium ammonium nitrate as well as Ni significantly influenced the grain yield and straw yield of wheat (table 6 and 7). The grain yield (32.75q ha^{-1}) and straw yield (47.18 q ha^{-1}) was obtained maximum with the application of urea at 120 kg N ha^{-1}whereas with the increasing levels of Ni application at Ni 2 kg ha^{-1}, maximum grain yield (34.93 q ha^{-1}) as well as the straw yield (47.38 q ha^{-1}) observed. Table 6 and 7 showed that the interaction effect was found significant. Maximum grain yield (44.58 q ha^{-1}) and straw yield (56.15 q ha^{-1}) was recorded with the combined effect of Ni at 2 kg $ha^{-1}$and urea application at 120 kg N ha^{-1}. The straw yield is closely related with vegetative growth viz; leaf number, tiller number and final plant stand. In presence of Ni, plants were able to utilize more nitrogen which ultimately increased the plant growth and development through better nitrogen metabolism. There are a number of reports that Ni ion (Ni^{2+}) prevents the destruction of chlorophyll during senescence of detached wheat and rice levels in the dark (Roach and Barclay, 1946) [19] and (Singh *et al*. 2011) [22]. According to (Gheibi *et al.* 2011) [11], urea plus nickel performed better compared to ammonium nitrate plus nickel.

The production of grain depends upon productive tillers, seed weight etc. which were possibly favourably affected by nickel application at 2 kg ha^{-1} level. According to (Mishra and Kar, 1974 [13] and Welch 1981) [27], an optimum dose of Ni in any crop would enhance grain or economic yield by virtue of its role in N metabolism as well its significant function in several metabolic activities like iron acquisition and phytoalexin synthesis. (Gerendas *et al.* 1999 a) [8] observed that the supplementing growth medium with 0.04 µm Ni enhanced dry matter production of urea grown plants significantly. (Pederson *et al.* 1985) [17] stated that protein synthesis was increased due to Ni application. Actually dry matter production is the result of various enzymatic activities. Of the seven Ni-dependent enzymes two have non-redox functions (urease and glyoxylase) and remaining five are involved in oxidation-reduction reactions (Brown, 2006) [1]. (Lavres *et al.* 2016) [12] also found increase in grain dry matter and aerial part dry matter yield by the application of Ni via seed treatment. (Singh *et al.* 2011) [22] reported that the dry matter yield (at 45 days after sowing, straw and grain) was significantly increased by the application of Ni at 1 and 2 kg ha^{-1} levels as compared to control.

3.3 Nutrient content

The data presented in table 8 and 9 on the effect of levels and sources of nitrogen and nickel on nitrogen content in grain and straw of wheat indicated that nitrogen content in grain and straw of wheat was significantly affected by different levels nickel and sources of nitrogen. The data pertaining to nitrogen content (1.83 and 0.548%) presented in (table 8 and 9) was recorded significantly higher with the application of urea at 120 kg N ha^{-1} over the application of ammonium sulphate (1.79 and 0.542%) and calcium ammonium nitrate (1.77 and 0.531%). The maximum nitrogen content in grain and straw due to Ni application was recorded in the treatment applied at 2 kg ha^{-1}(1.85 and 0.535%) over the other doses of nickel. The interaction effect was found significant and nitrogen content in grain and straw recorded significantly maximum (1.95 and 0.570%) with combined effect of Ni at 2 kg ha^{-1} and urea application. Table 10 and 11 shows the significant effect of levels and sources of nitrogen and nickel on nickel content in grain and straw of wheat crop. The maximum nickel content in grain and straw (0.200 and 0.385 ppm) as illustrated in table 10 and 11 was recorded significantly higher in the treatment supplied with nitrogen @120 kg ha^{-1} through urea over the other sources of nitrogen. In case of nickel application the maximum nickel content in grain and straw due to application of 4 kg ha^{-1} of nickel compared to the other doses of nickel. The interaction effect was also found to be significant regarding nickel content in grain and straw (table 10 and 11).Highest nickel content (0.370 and 0.850 ppm) was in treatment combination of 120 kg N ha^{-1} supplied with urea and 4 kg ha^{-1} of nickel. As it is well established fact that N fertilization in crop boosts up the growth due to its role in protein synthesis and vital plant metabolic activities, nitrogen application from different sources has shown positive influence on plant height, a measure of crop growth. The stimulating effect of a moderate Ni supply in urea grown plants is well documented in wide range of plants (Gerendas and Sattelmacher, 1997) [7]. Results were supported by the findings of (Palacios *et al.* 1998) [16] in tomato crop, the nitrogen (N) content in the plant increased significantly with increasing Ni treatments, showing a synergetic effect between Ni and N. Nitrogen and Ni concentration in the tops and roots increased with increasing levels of applied N and Ni, respectively (Singh *et al*. 1990) [21].

3.4 Nutrient Uptake

Table 12 and 13 shows that various treatments shows significant differences in nitrogen uptake by grain and straw of wheat. The minimum nitrogen uptake by grain and straw of wheat was observed in control plot (without nitrogen and nickel application). Application of nitrogen and nickel significantly increased the nitrogen uptake by grain and straw as compared to control. It was found highest with the treatment N_{120}UR (60.56 and 25.95 kg ha^{-1}) followed by N_{120}AS (55.05 and 24.60 kg ha^{-1}) and N_{120}CAN (49.87 and 23.15 kg ha^{-1}). The nitrogen uptake by grain and straw found significantly highest with the treatment Ni_2 (65.75 and 25.79 kg ha^{-1}). Due to interaction effect supplying 120 kg N ha^{-1}through urea + 2 kg ha^{-1} nickel registered significantly higher nitrogen uptake by grain and straw (86.93 and 32.00 kg ha^{-1}) than the other treatments. Application of N using urea, ammonium sulphate and calcium ammonium nitrate as well as Ni significantly influenced the nickel uptake by grain and straw of wheat (table 14 and 15). The nickel uptake grain (6.818 g ha^{-1}) and straw(18.327 g ha^{-1}) was obtained maximum with the application of urea at 120 kg N ha^{-1}whereas with the increasing levels of Ni application at Ni 4 kg ha^{-1}, maximum nickel uptake by grain (7.893 g ha^{-1}) as well as the straw (31.576 g ha^{-1}) observed. Table 14 and 15 showed that the interaction effect was found significant. Maximum nickel uptake by grain (12.036 g ha^{-1}) was recorded with the combined effect of Ni at 2 kg $ha^{-1}$and urea application at 120 kg N ha^{-1}but maximum nickel uptake by straw (36.660 g ha^{-1}) was recorded with the combined effect of Ni at 4 kg $ha^{-1}$and urea application at 120 kg N ha^{-1}. Passive diffusion and active transport are two main mechanisms which are responsible for the root uptake of Ni in the plant (Seregin and Kozhevnikova, 2006) [20].

Similar results were also reported by (Dahdoh 1995, Palacios, 1998) [3, 16] and Gad *et al.*, 2007 [6]. Dahdoh *et al.* (1995) [3] observed that the plant N content and uptake were increased by the addition of Ni. According to (Palacios *et al.*, 1998) [16], the nitrogen content in the plant increased significantly with increasing Ni treatments, showing a synergetic effect between Ni and N. Gad *et al.* (2007) [6] also reported a significant promotive effect on nitrogen, phosphorus and potassium content as compared to control by the application of Ni. Dahdoh *et al.* (1995) [3] reported the highest values of plant Ni content corresponded to urea treatment, while the lowest values were obtained under Ca $(NO_3)_2$ treatments. Also, addition of Ni increased the plant N content and uptake.

Table 1: Effect of levels and sources of N and levels of Ni on plant height (cm) at 45 DAS

Treatment	Ni_0	Ni_1	Ni_2	Ni_4	Mean
N_0	23.25	23.95	24.60	23.05	23.71
N_{120}UR	28.75	36.35	41.00	33.10	34.80
N_{120}AS	27.65	35.15	38.90	31.85	33.39
N_{120}CAN	27.00	34.75	38.50	31.25	32.87
Mean	26.66	32.55	35.75	29.81	
	Nitrogen (N)		Nickel (Ni)		Interaction
SEm ±	0.179		0.179		0.718
CD (P=0.05)	0.366		0.366		1.466

Table 2: Effect of levels and sources of N and levels of Ni on plant height (cm) at harvest

Treatment	Ni_0	Ni_1	Ni_2	Ni_4	Mean
N_0	52.15	60.35	68.25	52.00	58.19
N_{120}UR	85.20	96.15	101.75	92.35	93.86
N_{120}AS	83.40	95.35	100.85	91.30	92.72
N_{120}CAN	81.55	94.20	99.70	90.85	91.57
Mean	75.57	86.51	92.64	81.62	
	Nitrogen (N)		Nickel (Ni)		Interaction
SEm ±	0.297		0.297		1.186
CD (P=0.05)	0.606		0.606		2.423

Table 3: Effect of levels and sources of N and levels of Ni on number of tillers per plant at 45 DAS

Treatment	Ni_0	Ni_1	Ni_2	Ni_4	Mean
N_0	2.80	3.20	3.60	2.70	3.07
N_{120}UR	4.55	6.58	8.15	5.70	6.24
N_{120}AS	4.50	6.28	7.65	5.45	5.97
N_{120}CAN	4.25	6.15	7.35	5.40	5.79
Mean	4.02	5.55	6.69	4.81	
	Nitrogen (N)		Nickel (Ni)		Interaction
SEm ±	0.094		0.094		0.378
CD (P=0.05)	0.193		0.193		0.771

Table 4: Effect of levels and sources of N and levels of Ni on number of tillers per plant at harvest

Treatment	Ni_0	Ni_1	Ni_2	Ni_4	Mean
N_0	5.25	5.40	5.60	5.15	5.35
N_{120}UR	6.95	9.85	11.50	8.20	9.12
N_{120}AS	6.50	9.55	10.65	8.00	8.67
N_{120}CAN	6.20	9.10	10.45	7.65	8.35
Mean	6.22	8.47	9.55	7.25	
	Nitrogen (N)		Nickel (Ni)		Interaction
SEm ±	0.087		0.087		0.348
CD (P=0.05)	0.177		0.177		0.710

Table 5: Effect of levels and sources of N and levels of Ni on dry matter yield (q ha^{-1}) at 45 DAS

Treatment	Ni_0	Ni_1	Ni_2	Ni_4	Mean
N_0	7.55	7.95	8.15	7.50	7.79
N_{120}UR	10.15	12.75	14.20	11.65	12.19
N_{120}AS	9.90	12.35	13.45	11.15	11.71
N_{120}CAN	9.00	12.00	13.15	10.75	11.22
Mean	9.15	11.26	12.24	10.26	
	Nitrogen (N)		Nickel (Ni)		Interaction
SEm ±	0.179		0.179		0.718
CD (P=0.05)	0.367		0.367		1.466

Table 6: Effect of levels and sources of N and levels of Ni on grain yield (q ha^{-1})

Treatment	Ni_0	Ni_1	Ni_2	Ni_4	Mean
N_0	19.20	19.85	20.30	19.15	19.62
N_{120}UR	25.15	34.14	44.58	27.15	32.75
N_{120}AS	23.45	32.25	38.86	27.00	30.39
N_{120}CAN	21.35	29.00	36.00	25.35	27.92
Mean	22.29	28.81	34.93	24.66	
	Nitrogen (N)		Nickel (Ni)		Interaction
SEm ±	0.253		0.253		1.013
CD (P=0.05)	0.517		0.517		2.068

Table 7: Effect of levels and sources of N and levels of Ni on straw yield (q ha^{-1})

Treatment	Ni_0	Ni_1	Ni_2	Ni_4	Mean
N_0	31.75	32.95	34.15	32.00	32.71
N_{120}UR	41.44	48.00	56.15	43.13	47.18
N_{120}AS	41.14	47.15	50.32	42.46	45.27
N_{120}CAN	37.00	45.00	48.91	42.33	43.31
Mean	37.83	43.27	47.38	39.98	
	Nitrogen (N)		Nickel (Ni)		Interaction
SEm ±	0.275		0.275		1.100
CD (P=0.05)	0.562		0.562		2.247

Table 8: Effect of levels and sources of N and levels of Ni on nitrogen content (%) grain

Treatment	Ni_0	Ni_1	Ni_2	Ni_4	Mean
N_0	1.53	1.59	1.61	1.52	1.56
N_{120}UR	1.74	1.86	1.95	1.77	1.83
N_{120}AS	1.67	1.84	1.93	1.73	1.79
N_{120}CAN	1.64	1.81	1.90	1.72	1.77
Mean	1.64	1.77	1.85	1.68	
	Nitrogen (N)		Nickel (Ni)		Interaction
SEm ±	0.015		0.015		0.060
CD (P=0.05)	0.031		0.031		0.124

Table 9: Effect of levels and sources of N and levels of Ni on nitrogen content (%) in straw

Treatment	Ni_0	Ni_1	Ni_2	Ni_4	Mean
N_0	0.429	0.435	0.443	0.428	0.434
N_{120}UR	0.521	0.558	0.570	0.543	0.548
N_{120}AS	0.510	0.556	0.566	0.535	0.542
N_{120}CAN	0.483	0.550	0.563	0.530	0.531
Mean	0.486	0.525	0.535	0.509	
	Nitrogen (N)		Nickel (Ni)		Interaction
SEm ±	0.005		0.005		0.022
CD (P=0.05)	0.011		0.011		0.045

Table 10: Effect of levels and sources of N and levels of Ni on nickel content (ppm) in grain

Treatment	Ni_0	Ni_1	Ni_2	Ni_4	Mean
N_0	0.020	0.070	0.180	0.290	0.140
N_{120}UR	0.030	0.130	0.270	0.370	0.200
N_{120}AS	0.020	0.100	0.210	0.310	0.160
N_{120}CAN	0.020	0.090	0.190	0.300	0.150
Mean	0.022	0.097	0.212	0.317	
	Nitrogen (N)		Nickel (Ni)		Interaction
SEm ±	0.005		0.005		0.021
CD (P=0.05)	0.011		0.011		0.043

Table 11: Effect of levels and sources of N and levels of Ni on nickel content (ppm) in straw

Treatment	Ni_0	Ni_1	Ni_2	Ni_4	Mean
N_0	0.030	0.145	0.365	0.675	0.304
N_{120}UR	0.040	0.185	0.465	0.850	0.385
N_{120}AS	0.030	0.170	0.435	0.805	0.360
N_{120}CAN	0.030	0.165	0.375	0.800	0.342
Mean	0.032	0.166	0.410	0.782	
	Nitrogen (N)		Nickel (Ni)		Interaction
SEm ±	0.006		0.006		0.025
CD (P=0.05)	0.013		0.013		0.051

Table 12: Effect of levels and sources of N and levels of Ni on uptake of nitrogen (kg ha^{-1}) by grain

Treatment	Ni_0	Ni_1	Ni_2	Ni_4	Mean
N_0	29.38	31.56	32.68	29.11	30.68
N_{120}UR	43.76	63.50	86.93	48.05	60.56
N_{120}AS	39.16	59.34	74.99	46.71	55.05
N_{120}CAN	35.01	52.49	68.40	43.60	49.87
Mean	36.83	51.72	65.75	41.87	
	Nitrogen (N)		Nickel (Ni)		Interaction
SEm ±	0.455		0.455		1.819
CD (P=0.05)	0.929		0.929		3.714

Table 13: Effect of levels and sources of N and levels of Ni on uptake of nitrogen (kg ha^{-1}) by straw

Treatment	Ni_0	Ni_1	Ni_2	Ni_4	Mean
N_0	13.62	14.33	15.13	13.70	14.19
N_{120}UR	21.59	26.78	32.00	23.42	25.95
N_{120}AS	20.98	26.21	28.48	22.72	24.60
N_{120}CAN	17.87	24.75	27.54	22.43	23.15
Mean	18.51	23.02	25.79	20.57	
	Nitrogen (N)		Nickel (Ni)		Interaction
SEm ±	0.381		0.381		1.525
CD (P=0.05)	0.778		0.778		3.114

Table 14: Effect of levels and sources of N and levels of Ni on uptake of nickel (g ha^{-1}) by grain

Treatment	Ni_0	Ni_1	Ni_2	Ni_4	Mean
N_0	0.384	1.389	3.654	5.553	2.745
N_{120}UR	0.754	4.438	12.036	10.045	6.818
N_{120}AS	0.469	3.225	8.160	8.370	5.056
N_{120}CAN	0.427	2.610	6.840	7.605	4.370
Mean	0.508	2.915	7.672	7.893	
	Nitrogen (N)		Nickel (Ni)		Interaction
SEm ±	0.046		0.046		0.182
CD (P=0.05)	0.093		0.093		0.372

Table 15: Effect of levels and sources of N and levels of Ni on uptake of nickel (g ha^{-1}) by straw

Treatment	Ni_0	Ni_1	Ni_2	Ni_4	Mean
N_0	0.952	4.778	12.465	21.600	9.949
N_{120}UR	1.658	8.880	26.110	36.660	18.327
N_{120}AS	1.234	8.015	21.889	34.180	16.329
N_{120}CAN	1.110	7.425	18.341	33.864	15.185
Mean	1.238	7.274	19.701	31.576	
	Nitrogen (N)		Nickel (Ni)		Interaction
SEm ±	0.145		0.145		0.581
CD (P=0.05)	0.296		0.296		1.186

4. Conclusion

Combined effect of Ni at 2 kg ha^{-1} with urea at 120 kg N ha^{-1} recorded maximum growth and dry matter yield of wheat as compared to other sources of nitrogen. However, nitrogen and nickel content in and their respective uptake were maximum with urea at 120 kg N ha^{-1} plus Ni at 4 kg ha^{-1}.

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