International Journal of Statistics and Applied Mathematics

ISSN: 2456-1452
Maths 2023; SP-8(6): 575-579
© 2023 Stats & Maths
https://www.mathsjournal.com
Received: 13-09-2023
Accepted: 17-10-2023

Sumeet Baranwal
Department of Agricultural Chemistry and Soil Science, Udai Pratap (Autonomous) College, Varanasi, Uttar Pradesh, India

RP Singh
Department of Agricultural Chemistry and Soil Science, Udai Pratap (Autonomous) College, Varanasi, Uttar Pradesh, India

SK Patel
Department of Agricultural Chemistry and Soil Science, Udai Pratap (Autonomous) College, Varanasi, Uttar Pradesh, India

OP Pandey
Department of Agricultural Chemistry and Soil Science, Udai Pratap (Autonomous) College, Varanasi, Uttar Pradesh, India

Shivam Singh
Department of Soil Science and Agricultural Chemistry, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, Uttar Pradesh, India

Shashi Prakash Vishwakarma
IRS, Madhepura, Bihar Agriculture University, Sabour, Punjab, India

Richa Raghuvanshi
Department of Soil Science and Agricultural Chemistry, Bihar Agriculture University. Sabour, Bihar, India

Corresponding Author:
Richa Raghuvanshi
Department of Soil Science and Agricultural Chemistry, Bihar Agriculture University. Sabour, Bihar, India

Effect of nickel on growth and yield of green gram (*Vigna radiata* L.)

Sumeet Baranwal, RP Singh, SK Patel, OP Pandey, Shivam Singh, Shashi Prakash Vishwakarma and Richa Raghuvanshi

Abstract
Ni is considered as an essential element primarily because of its function as an irreplaceable component of urease which is responsible for the hydrolysis of urea N. Urea N acquired by plant is not available for plant N metabolism unless hydrolyzed to CO_2 and NH_3. Ni deficiency in legumes and other dicots causes a decrease in the activity of enzyme urease, a condition that causes accumulation of toxic levels of urea and is manifested as necrosis at the tip of the leaves. A field experiment was conducted during *Zaid* season of 2021on research plot of Udai Pratap (Autonomous) College, Varanasi (U.P.) adjoining the Department of Agricultural Chemistry and Soil Science. The physicochemical properties of the experimental soil were; pH (7.43), EC (0.48 dS m^{-1}); organic carbon (0.55%), available nitrogen (243.18 kg ha^{-1}), available phosphorus (18.32 kg ha^{-1}), available potassium (212.30 kg ha^{-1}), available nickel (Trace). The experiment was carried out in randomized block design (RBD) with six treatments and three replications. Treatment were T_0 = Control (RDF N: P: K), T_1 = RDF+ Ni @ 0.50 kg ha^{-1}, T_2 = RDF + Ni @ 1.00 kg ha^{-1}, T_3 = RDF + Ni @ 1.50 kg ha^{-1}, T_4 = RDF+ Ni @ 2.00 kg ha^{-1}, T_5 = RDF + Ni @ 2.50 kg ha^{-1}. The growth parameters (plant height, number of leaves and number of branches) were significantly increased by different treatments. The minimum value was recorded with control (without nickel) and maximum with treatment T_4 (Ni @ 2 kg ha^{-1}) at 15, 30, 45 and 60 days after sowing. Application of nickel at different levels increased the dry matter production. Highest seed and stover yields were recorded with treatment comprising Ni @ 2 kg ha^{-1}. All the treatments have significant effect in case of N, P and K content in stover. The minimum concentration of N, P and K was recorded in case of control and maximum in T_4. Similar trend was also found in case of N, P and K uptake by stover. Available N, P and K status of postharvest soil were also significantly affected by different treatments. The minimum amounts were recorded with treatment T_0 (without nickel) and maximum with treatment T_4 (Ni @ 2 kg ha^{-1}). The application of nickel significantly affected the growth**,** yield and nutrient uptake by green gram. The available N, P and K status of post-harvest soil was also increased. The application of 2.0 kg ha^{-1} with20 kg N ha^{-1}, 50 kg P_2O_5 ha^{-1} and 40 kg K_2O ha^{-1} was found to be the best treatment regarding growth, yield, nutrients uptake and N, P and K status of soil.

Keywords: Ni, legume, green gram, nutrient uptake

Introduction
Pulses are consumed as Dal, which is a cheap source of plant protein. These are consumed because of body building properties having presence of various amino acids. These also have medicinal properties. By products of pulses like leaves, pod coats and bran are given to animals in the form of dry fodder. Some pulse crops like Gram, Lobia, Urdbean & Moongbean are fed to animals as green fodder. Moong plants are also used as green manure which improve soil health and adds nutrient into the soil.

India has made remarkable progress in enhancing production of pulses during the past 15 years. During 2005-06, the total production of pulses in India was 13.38 million MT, which increased to 25.58 million MT during 2020-21. Currently, 24 mt production of pulses yields dal (Milled pulse) fit for human consumption of 18 mt after accounting for seeding and milling losses. In 2020, about 48 grams of pulses was available per capita daily in India. This was a decrease compared to the previous year. Rice and wheat had a higher per capita daily availability and had a higher consumption rate among food grains during the measured time period.

Green gram scientifically known as (*Vigna radiata*) is a plant species in the legume family and commonly called as mung bean, moong in India. India is its primary origin and is mainly cultivated in East Asia, Southeast Asia and the Indian subcontinent. It is the third important pulse crop of India grown in nearly 16 per cent of the total pulse area of the country. It contains protein rich seed with 20-25% protein and sometimes plants are cut and ploughed into the soil to enrich soil nitrogen. India is the major producer of green gram in the world and grown in almost all the States. It is grown in about 4.5 million hectares with the total production of 2.5 million tonnes with a productivity of 548 kg/ha and contributing 10% to the total pulse production. According to Government of India, 3rd advance estimates, green gram production in 2020-21 is at 2.64 million tonnes.

Ni is the most recent candidate to be added in the list of essential nutrients for higher plant although failure to complete the life cycle in absence of Ni has only been demonstrated in a few plant species. Ni is considered as an essential element primarily because of its function as an irreplaceable component of urease which is responsible for the hydrolysis of urea N. Urea N acquired by plant is not available for plant N metabolism unless hydrolyzed to CO_2 and NH_3. Consequently, urea grown plants are highly sensitive to inadequate Ni supply (Gerendas and Sattelmacher 1999a) [29]. Ni was soon found essential to legumes (Eskew *et al.*, 1983, 1984) [22-23] and subsequently was found essential to several temperate cereal crops (Brown *et al.*, 1987a, 1987b, 1990) [7-9]. Seed treatment with cobalt, molybdenum and Brady rhizobium strains has been widely practiced to improve crops. Additionally, seed treatment together with Ni fertilization of soybean might improve the efficiency of biological nitrogen fixation (BNF), boosting grain dry matter yield and N content (Lavres *et al.*, 2016) [42]. Yossef *et al.* (1998) [65] reported that Ni deficiency resulted in marked disruption of N metabolism, malate and amino acids in barley while application of Ni at 30 mg/kg soil enhanced dry matter. Moreover, Khan *et al.* (1999) [37] found that addition of 0.05 mg Ni/liter to nutrient solution gave the best results in terms of qualitative and quantitative characteristics of spinach. The studies forwarded by Roach and Barclay (1946) [56] in plants of potato (*Solanum tuberosum*), wheat (*Triticum aestivum*) and bean (*Phaseolus vulgaris*) in England indicated an increase in plant production as a result of foliar application of Ni. Additionally, Cataldo *et al.* (1978) [10] studied the dynamics and transport of Ni in soybean plants.

Ni deficiency in legumes and other dicots causes a decrease in the activity of enzyme urease, a condition that causes accumulation of toxic levels of urea and is manifested as necrosis at the tip of the leaves (Eskew *et al.* 1983; Walker *et al.* 1985; Malavolta and Moraes, 2007) [21, 32, 44].

Materials and Methods

Experimental site characteristics

The field experiment was conducted during zaid season of 2021 on research plot of the Department of Agricultural Chemistry and Soil Science. The experiment was carried out in randomized block design (RBD) with six treatments and three replications. The treatments were replicated thrice making the total number of 18 plots. Treatment were T_0 = Control (RDF N: P: K), T_1 = RDF+ Ni @ 0.50 kg ha^{-1}, T_2 = RDF + Ni @ 1.00 kg ha^{-1}, T_3 = RDF + Ni @ 1.50 kg ha^{-1}, T_4 = RDF+ Ni @ 2.00 kg ha^{-1}, T_5 = RDF + Ni @ 2.50 kg ha^{-1}. Plant nutrients such as N, P, K and Ni were applied through chemical fertilizers. Full dose of nitrogen (20 kg ha^{-1}), phosphorus (50 kg ha^{-1}) and potassium (40 kg ha^{-1}), Ni was applied as basal application at the time of sowing.

Soil and plant analysis

Soil samples were collected at 0-15cm depth after harvest of the crop and analyzed by standard method of analysis. Soil reaction (pH) was determined using soil: water suspension (1:2.5) with the help of glass electrode digital pH meter (Jackson, 1973) [33], EC by TDS meter, O.C. by Walkley and Black's rapid titration method (Walkley and Black, 1934) [62], available N by alkaline permanganate method (Subbiah and Asija, 1956) [61], available P_2O_5, available K_2O by 1N neutral ammonium acetate method (Jackson, 1973) [33], DTPA extractable Ni in soil by atomic absorption spectrophotometry (Lindsay and Norvell, 1978) [23]. Plant samples were also collected and dried at 70 ^{0}C for 12 hours. 0.5-gram ground plant sample was digested in sulphuric acid and perchloric acid with the ratio of 9:1 and digested samples were used to determine the nitrogen by micro Kjeldahl's method, phosphorus by spectrophotometer and potassium by flame photometer (Jackson, 1973) [33]. Ni concentration was determined using spectrophotometer and atomic absorption spectrophotometer respectively.

Results and Discussion

Growth attributes

The data obtained in respect of growth attributes at different growth stages under the use of boron and manganese have been presented in table 1. The average plant height under different treatments at 30 DAS varied from 19.55 to 23.40 cm at 45 DAS varied from 28.63 to 36.70 cm and at 60 DAS varied from 32.62 to 41.74 cm. Effect of Ni on plant height at 30 DAS, 45 DAS and 60 DAS were statistically significant. Application of Ni significantly increased the plant height as compared to control.

The observations related to number of leaves recorded at 30 DAS showed that number of leaves varied from 10.38 to 13.38 among all the treatments. The maximum number of plant leaves recorded in case of treatment T_4 (13.38) and minimum was recorded in treatment T_0 (10.38). Number of leaves per plant among all treatments at 45 DAS ranged from 13.49 to 20.44. The maximum number of leaves recorded in case of treatment T_4 (20.44) and minimum was recorded in treatment T_0 (13.49). Number of leaves per plant among all treatments at 60 DAS ranged from 15.77 to 21.75. The maximum number of leaves recorded in case of treatment T_4 (21.75) and minimum was recorded in treatment T_0 (15.77). Maximum number of leaves at all the stage was found in the treatment T_4 due to more vegetative growth led by availability in optimum amount in comparison to other treatments. The observation recorded on number of branches $plant^{-1}$ has been presented in table. It is clear from the data that the maximum number of branches were found with the treatment T_4 at all the stages of observation recorded. At 45 DAS number of branches varied from 6.84 to 11.35. Effect of different treatments was found to be statistically significant. The second observation related to number of branches $plant^{-1}$ was recorded at 60 days after sowing. At this stage number of branches varied from 9.56 to 13.54. However, effect of different treatments was found to be statistically significant at this stage.

Yield attributes

Application of B and Mn significantly increased the pods number as compared to control (table 2). The highest number of pods were recorded with the treatment T_4 (13.45) and lowest with the treatment T_0 (14.33). T_4 was found to be significantly superior over T_4 and T_1.

It is evident from table 2 that 1000 seed weight (Test weight) varied from 23.76 to 43.63 g. Significant response was observed due to Ni application. The maximum test weight (43.63 g) was recorded with application of Ni @ 2.00 kg ha^{-1} and minimum (23.76) was noted with control. T_4 was found to be significantly superior over all the other treatments.

Data on seed yield has been presented in table 2. The seed yield under different treatments was 11.4512.64, 13.52, 13.97, 15.23 and 14.36 q ha^{-1} respectively for T_0, T_1, T_2, T_3, T_4 and T_5. Application of Ni significantly increased the seed yield as compared to control. T_4 recorded maximum yield and was found to be significantly superior over other treatments.

Data presented in table 2 revealed that application of different levels of Ni increased the stover yield as compared to control. Highest stover yield was found with treatment T_4. Mean stover yield was 19.22, 19.98, 20.40, 21.01, 22.57 and 21.64 q ha^{-1} respectively for T_0, T_1, T_2, T_3, T_4 and T_5. T_4 was found to be significantly superior over all the other treatments.

Nutrient concentration and uptake

N, P, K and Ni concentration in plant

The data related to N, P, K and Ni concentration in plant (Stover) has been presented in table 3. Results revealed that soil applied Ni significantly increased N, P, K and Ni concentration in plant (stover) when compared to control.. The effect of Among the treatments, the concentration of N varied from 2.83 to 3.99%. Maximum phosphorus concentration in stover was found with the treatment T_4 and minimum with T_0. The concentration varied from 0.09 to 0.23%. Among different treatments, the content of K varied from 0.63 to 0.79%. The maximum content was found with T_4 and minimum with T_0 (Control). It was also noted that effect of T_4 was found to be significantly superior.

Nutrient uptake

The data related to N, P, K and Ni uptake under different treatments by green gram crop is presented in table 3.

Nutrient uptake by the plant (stover) was increased significantly by the addition of Ni over control. Among various treatments, the uptake of N by plant (stover) varied from 54.38 to 86.36 kg ha^{-1}. Phosphorus uptake varied from 1.72 to 5.19 kg ha^{-1}. Among various treatments, the uptake of K by plant (stover) varied from 12.20 to 17.32 kg ha^{-1}. T_4 recorded maximum uptake. Soil applied Ni at different levels significantly increased the Ni uptake.

Table 1: Effect of treatments on growth attributes at different growth stages

Treatment	Plant height (cm)			Number of leaves plant $^{-1}$			No. of branches plant^{-1}		
	30 DAS	45 DAS	60 DAS	30 DAS	45 DAS	60 DAS	30 DAS	45 DAS	60 DAS
T_0	19.55	28.63	32.62	10.38	13.49	15.77	3.03	6.84	9.56
T_1	20.06	30.76	36.50	11.69	16.56	16.80	3.37	7.67	10.59
T_2	20.90	31.48	37.56	12.43	17.28	17.49	3.58	8.29	11.47
T_3	21.65	32.06	38.00	12.71	18.19	18.75	4.09	8.88	12.03
T_4	23.40	36.70	41.74	13.38	20.44	21.75	4.71	11.35	13.54
T_5	22.49	34.07	39.52	12.84	19.54	19.86	4.17	9.40	12.47
SEm±	0.213	0.567	0.596	0.235	0.072	0.146	0.0854	0.183	0.126
CD(P=0.05)	0.684	1.788	1.879	0.742	0.227	0.461	0.269	0.578	0.399

DAS= Days After Sowing

Table 2: Effect of treatments on yield attributes

Treatment	No. of pod plant^{-1}	Test (1000 seed) wt. (g)	Seed yield (q ha^{-1})	Stover yield (q ha^{-1})
T_0	9.63	23.76	11.45	19.22
T_1	10.55	32.55	12.64	19.98
T_2	10.88	34.78	13.52	20.40
T_3	12.01	37.44	13.97	21.01
T_4	13.45	43.63	15.23	22.57
T_5	12.50	39.93	14.36	21.64
SEm±	0.142	0.844	0.217	0.321
CD(P=0.05)	0.449	2.660	0.684	1.011

Table 3: Effect of treatments on nutrient concentration and uptake by stover

Treatment	Nutrient concentration				Nutrient uptake			
	N (%)	P (%)	K (%)	Ni (ppm)	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	Ni (g ha^{-1})
T_0	2.83	0.09	0.63	0.06	54.38	1.72	12.20	01.15
T_1	3.12	0.14	0.68	1.10	62.37	2.82	13.58	21.97
T_2	3.29	0.17	0.71	2.23	67.68	3.47	14.45	45.49
T_3	3.49	0.19	0.75	2.36	73.58	3.95	15.79	49.58
T_4	3.99	0.23	0.79	3.12	86.36	5.19	17.32	70.41
T_5	3.79	0.21	0.77	4.60	85.35	3.71	17.24	99.54
SEm±	0.06	0.01	0.01	0.086	0.70	0.08	0.19	04.90
CD(P=0.05)	0.19	0.03	0.04	0.273	2.20	0.25	0.63	15.60

References

1. Ahamd MSA, Husain M, Asharif M, Ahmad R, Ashraf MF. Effect of nickel on seed germ inability of some elite sunflower (*Helianthus annuus* L.) cultivars. Pakistan Journal of Botany. 2009;41:1871-1882.
2. Atta-Aly, Mordy A. Effect of nickel addition on the yield and quality of parsley leaves. Scientia Horticulture. 1999;82:9-24.
3. Aziz EE, Nadia G, Nadia M, Badran M. Effect of cobalt and nickel on plant growth, yield and flavonoids content

of *Hibiscus sabdariffa* L. Australian Journal of Basic and Applied Sciences. 2007;1:73-78.

4. Bai C, Reilly CC, Wood BW. Nickel deficiency disrupts metabolism of ureides, amino acids and organic acids of young pecan foliage. Plant Physiology. 2006;140:433-443.
5. Bower CA, Wilcox LV. Soluble Salts. In 'Methods of soil analysis', American Society of Agronomy, Inc. Madison, Wisconsin. U.S.A. 1965;2:933-951.
6. Brown PH, Barker AV, Pilbeam DJ. Nickel. In Handbook of Plant Nutrition; c2006. p. 395–410.
7. Brown PH, Welch RM, Cary EE. Nickel: A micronutrient essential for higher plant. Plant Physiology. 1987a;85:801-803.
8. Brown PH, Welch RM, Cary EE. Beneficial effect of nickel on plant growth. Journal of Plant Nutrition. 1987b;10:1447-1455.
9. Brown PH, Welch RM, Madison JT. Effect of nickel deficiency on soluble anion, amino acid, and nitrogen levels in barley. Plant and Soil. 1990;125:19-27.
10. Cataldo D, Garland T, Wildung R, Drucker H. Nickel in plants. II. Distribution and chemical form in soybean plants. Plant Physiology. 1978;62:566-570.
11. Chandel SKS, Singh RP, Yadav PK, Singh SN, Singh DK. Effect of Ni on S uptake and dry matter yield of wheat. Crop Research. 2011;41:10-12.
12. Chandel SRS. A Hand Book of Agricultural Statistics. Achal Prakashan Mandir 117 / 574, Pandu Nagar Kanpur; c(2014. p. 17-35.
13. Chandrashekhar G. Make pulses policy demand centric market commodities: Business line. (The Hindu); c2021.
14. Cheng B, Reilly CC, Wood BW. Nickel deficiency affects nitrogenous forms and urease activity in spring xylem sap of pecan. Journal of the American Society for Horticultural Science. 2007;132:302-309.
15. Dahdoh MSA, El-Kadi AH, Soliman S. Response oelf alfalfa plant growth in calcareous soil to nickel and nitrogen source. Egyptian Journal of Soil Science. 1995;35:337-346.
16. Dalton DA, Russell SA, Evans HJ. Nickel as a micronutrient element for plants. Bio factors. 198;1:11-16.
17. Das PK, Kar M, Mishra D. Nickel nutrition of plants: I. Effect of nickel on some oxidase activities during rice (*Oryza sativa* L.) seed germination. Zeitschrift Fur Pflanzenphysiologie. 1978;90:225-233.
18. Dixon NE, Gazzola C, Blakely RL, Zerner B. Jack bean urease (EC 3.5, 1.5). III. The involvement of active-site nickel ion in inhibition by β- mercaptoethanol, phosphoramidate, and fluoride. Canadian Journal ofBiochemistry. 1980;58:481-488.
19. Dunemann L, Wiren Von N, Schulz R, Marschner H. Speciation analysis of nickel in soil solution and availability to oat plants. Plant and Soil. 1991;133:263-269.
20. Elkhatib EA. Evaluation of six soil extractants for assessing nickel availability to wheat. Arid Soil Research and Rehabilitation. 1994;8:137-145.
21. Eskew DL, Welch RM, Cary EE. Nickel an essential micronutrient for legumes and possibly all higher plants. Science. 1983;222:621-623.
22. Eskew DL, Welch RM, Cary EE. A simple plant nutrition solution purification method for effective removal of trace metals using controlled pore glass-8-hydroxy quinoline chelation column chromatography. Plant Physiology. 1984 a;76:103-105.
23. Eskew DL, Welch RM, Norvell WA. Nickel in higher plants: Further evidence for an essential role. Plant Physiology. 1984 b;76:691-693.
24. Fabiano CC, Tezotto T, Favarin JL, Polacco JC, Mazzafera P. Essentiality of nickel in plants: A role in plant stresses. Frontierin Plant Science; c2015. p. 6.
25. Freitas DS, Rodak BW, Reis ARD, Reis FDB, Carvalho TSD, Schulze J, *et al*. Hidden nickel deficiency nickel fertilization via soil improves nitrogen metabolism and grain yield in soybean genotypes. Frontiers in Plant Science. 2018;9:1-16.
26. Nadia G, El-Sherif MH, El-Gereedly NHM. Influence of nickel on some physiological aspects of tomato plants. Australian Journal of Basic and Applied Sciences. 2007;1:286-293.
27. Gajewska E, Skłodowska M, Słaba M, Mazur J. Effect of nickel on antioxidative enzyme activities, proline and chlorophyll contents in wheat shoots. Biologia Plantarum. 2006;50:653-659.
28. Gerendas J, Sattelmacher B. Significance of Ni supply for growth, urease activity and the concentrations of urea, amino acids and mineral nutrients of urea-grown plants. Plant and soil. 1997;190:153-162.
29. Gerendas J, Sattelmacher B. Influence of Ni supply on growth and nitrogen metabolism of *Brassica napus* L. grown with NH_4NO_3 or urea as N source. Annals of Botany. 1999 a;83:65–71.
30. Gerendas J, Polacco JC, Freyermuthy SK, Sattelmacher B. Significance of nickel for plant growth and metabolism. Journal of Plant Nutrition and Soil Science. 1999 b;162:241-256.
31. Gheibi MN, Kholdebarin B, Malakouti MJ, Ghanati F, Teimouri S, Sayadi R, *et al*. Effect of various nickel levels on growth and chlorophyll content of corn plants supplied with urea and ammonium nitrate. Food Agriculture and Environment. 2011;9:583-587.
32. Graham RD, Welch RM, Walker CD. A role of nickel in the resistance of plants to rust. Australian Agronomy Society Proceeding; c1985.p. 159.
33. Jackson ML. Soil Chemical Analysis. Prentic Hall of India Pvt. Ltd. New Delhi; c1973. p. 183-204.
34. Jimenez MT, Galvan A, Fernandez E, Llamas A. Homeostas is of the micronutrients Ni, Mo and Cl with specific biochemical functions. Plant Biology. 2009;12:358-363.
35. Kamboj N, Malik RS, Dhanker P, Kumar A. Importance of nickel in crops. Journal of Pharmacognosy and Phytochemistry. 2018;7:3470-3475.
36. Khan MR, Khan MM. Effect of varying concentration of nickel and cobalt on the plant growth and yield of chickpea. Australian Journal of Basic and Applied Sciences. 2010;4:1036-1046.
37. Khan NK, Watanabe M, Watanabe Y. Effect of different concentrations of urea with or without nickel addition on spinach (*Spinacia oleracea* E.) growth under hydroponic culture. Soil Science and Plant Nutrition. 1999;45:569-575.
38. Krogmeier MJ, McCarty GW, Shogren DR, Bremner JM. Effect of nickel deficiency in soybeans on the phytotoxicity of foliar-applied urea. Plant and Soil. 1991;135:283-286.
39. Kumar D, Ramani VP, Patel KC, Shukla AK. Establishing Critical Limits for Nickel in Soil and Plant

for Predicting the Response of Spinach (*Spinacia oleracea*). Journal of the Indian Society of Soil Science. 2021;69:105-110.
40. Kumar O, Singh SK, Singh AP, Yadav SN, Latare AM. Effect of soil application of nickel on growth, micronutrient, concentration and uptake in barley (*Hordeum vulgare* L.) grown in Inceptisols of Varanasi. Journal of Plant Nutrition. 2018;41:50-66.
41. Hevillier LL, Edighoffer S. Extractibility of nickel and its concentration in cultivated plants in Ni rich ultramafic soils of Caledenia. Plant and Soil. 1996;186:255-264.
42. Lavres J, Franco CG, de Sousa Camara GM. Soybean seed treatment with nickel improves biological nitrogen fixation and urease activity. Frontiers of Environmental Science. 2016;37:1-11.
43. Lee J, Brooks RR, Reeves RD, Boswell CR. Molybdenum nutrition of rice under low and high nitrogen level. Plant and Soil. 1977;46:681-685.
44. Malavolta E, Moraes MF. Nickel - from toxic to essential nutrient. Better crops. 2007;91:3.
45. Mishra D, Padmakar M. Nickel in plant growth and metabolism. Botanical Review. 1974;40:395-452.
46. Olsen SR, Cole CV, Watanable FS, Deam LA. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. United State Department Agriculture Circular; c1954. p. 939.
47. Kumar O, Singh SK, Patra A, Latare A, Yadav SN. A comparative study of soil and foliar nickel application on growth, yield and nutritional quality of Barley (*Hordeum Vulgare* L.) grown in Inceptisol. Communications in Soil Science and Plant Analysis. 2021;52:1207-1223.
48. Palacios G, Gomez I, Barrachina AC, Pedreno JN, Mataix J. Effect of nickel concentration on tomato plant nutrition and dry matter yield. Journal of Plant Nutrition. 1998;21:2179-2191.
49. Pannu P, Patel HM, Mehta PV, Kumar A. Nickel and nitrogen sources (urea and ammonium sulphate) affecting growth, yield and quality in maize plant (*Zea mays*). The Pharma Innovation. 2018;7:80-84.
50. Pederson DM, Dady A, Smith GD. the use of nickel to probe the role of hydrogen metabolism in cyanobacterial nitrogen fixation. Biochemistry. 1985;68:113-120.
51. Polacco JC. Is nickel a universal component of plant ureases? Plant Science Letters. 1977;10:249-255.
52. Polacco JC. Nitrogen metabolism in soybean tissue culture II. Urea utilization and urease synthesis require Ni^{2+}. Plant Physiology. 1977;59:827-830.
53. Gaur P. Can India sustains high growth of pulses production? Journal of Food Legumes. 2021;34:1-3.
54. Rabie MH, Abdel L, Nofal EA, Asy KG, Eleiwa METhe effect of nickel on plants. (III) The effect of foliar nickel on yield and elemental content of some crops. Journal of King Abdulaziz University-Science. 1992;4:15-21.
55. Rahman H, Sabreen S, Alam S, Kawai S. Effects of nickel on growth and composition of metal micronutrients in barley plants grown in nutrient solution. Journal of Plant Nutrition. 2005;28:393-404.
56. Roach WA, Barclay C. Nickel and Multiple Trace Deficiencies in Agricultural Crops. Nature. 1946;157:696.
57. Shahzad B, Tanveer M, Rehman A, Cheema SA, Fahad S, Rehman S. Nickel; whether toxic or essential for plants and environment-A review. Plant Physiology and Biochemistry. 2018;132:641-651.
58. Singh MK, Shrivastava S, Patel SK, Chandel SKS, Singh RP, Yadav PK. Effect of nickel with different sources of nitrogen on rice (*Oryza sativa* L.). Journal of Pharmacognosy and Phytochemistry. 2020a;9:1110-1112.
59. Singh MK, Singh RP, Chandel SKS, Yadav PK, Singh SN. Effect of Ni and N sources on wheat (*Triticum aestivum* L.). International Journal of Agriculture Science. 2020 b;12:9672-9675.
60. Singh MK, Singh RP, Yadav PK, Chandel SKS, Singh SN. Effect of Ni and N sources on wheat (*Triticum aestivum* L.) yield and nutrient uptake. The Pharma Innovation. 2020c;9:390-395.
61. Subbiah BV, Asija GL. A rapid procedure for the determination of available nitrogen in soils. Current Science. 1956;25:259-260.
62. Walkley A, Black CA. An examination of degtjareff method for determining soil organic matter and proposed modifications of the chromic acid method. Soil Science. 1934;37:29-38.
63. Welch RM. The biological significance of nickel. Journal of Plant Nutrition. 1981;3:345-356.
64. Willaert G, Verloo M. Biological effects of nickel species and their determination in plant and soil. Plant and Soil. 1988;107:285-292.
65. Yossef RA, Hegazy MNA, Abdel-Fattah A. Micronutrients in corn plants as affected by the addition of N with Ni or Cd. Egyptian Journal of Soil Science. 1998;3:427-437.
66. Yusuf M, Fariduddin Q, Hayat S, Ahma AA. Nickel: An overview of uptake, essentiality and toxicity in plants. Bulletin of Environmental Contamination and Toxicology. 2011;86:1–17.