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Growth, Yield and Cadmium Accumulation in Wheat Crop (*Triticum aestivum* L.) as Influenced by Nitrogenous Fertilizer in an Inceptisol of Varanasi, India

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ABSTRACT

A pot experiment was conducted to explore the growth, yield and cadmium accumulation in wheat Crop *(Triticum aestivum* L.) as Influenced by nitrogenous fertilizer in an Inceptisol of Varanasi, India. The findings indicated that the uptake of cadmium by wheat crop roots and shoots increased with increasing nitrogen doses up to 180 kg/ha over control. In the case of 5 mg/kg cadmium concentration, the average cadmium concentration content increased by 0.3, 0.4, and 0.633 at 60,120, and 180 kg/ha, respectively, over control. At Cadmium 10 mg/kg concentration, there was a similar degree of progress. Cadmium accumulation was found more in roots than shoots. However, with increasing nitrogen rates, crop growth, chlorophyll content, and spike length all increased significantly. The tillers per plant and grains per ear or spike, i.e. overall grain yield was increased significantly throughout the experiment, the concentrations of phosphorus, potassium, calcium, and magnesium remained stable. The findings of this study will help agronomists assess the danger of elevated Cd content in various wheat cultivars as a result of regional crop and soil management strategies, particularly those involving nitrogen.

Key words: *Cadmium, Nitrogen uptake, Wheat, Phytoavailability, Growth and Yield*

Introduction

Wheat is the main cereal crop of India. The country's entire cropland area is estimated to be at 29.8 million hectares. Wheat output has increased dramatically in the country, from 75.81 million MT in 2006-07 to an all-time high of 94.88 million MT in 2011-12. India is the world's second-largest wheat producer. In recent years, wheat productivity has climbed to 3140 kg/hectare. In modern era, Heavy metal toxicity is one of the important topics of concern for agricultural background. Generally, Heavy metal is a group of metals or metalloids (such as Arsenic) that have higher relative density compared to water and are very much toxic even at low concentration. Cadmium is one of the vital elements among those

heavy metal compounds. Industrial activities, such as refining, mining and plastic manufacturing are the main sources of cadmium. Severe farmlands have been polluted by metals through industrial emissions, fertilizers and urban waste. Heavy metals are mainly involved in the oxidation –reduction procedures of plant metabolism. Cadmium is also not so much different from that. Its toxicity is also associated with diminished plant growth, enzyme activity and metabolism. Usually Cadmium concentration is varying from (0.32- 1.0) micromole in soil solution. This is regarded as moderate level cadmium pollution. Cereal crop cultivars can store high cadmium in grains and straws also. More than 40% of Cd can be absorbed and transported to the upper parts of the cereal crops and it may harm directly (grains) and indirectly (animals) the human health. Consequently, appropriate methods should apply to decrease heavy metal accumulation in crops and protect living organisms. The uptake of cadmium is totally depend on its concentration in soil solution and other factors like organic matter, pH, Redox potential, temperature and concentration of the other elements. Nowadays, It has been observed that the nitrogenous fertilizers are gradually effected the cadmium uptake in wheat crop. Due to the heavy amount of nitrogenous fertilizers used in the wheat crop fields this type of heavy metal (cadmium) toxicity risk will always be present for crop cultivation. A growth chamber experiment was conducted to investigate the effect of nitrogen fertilizer on the chemical composition of the soil solution over time, as well as to assess Cd uptake as a function of nitrogen fertiliser application rates and transpiration rates. Sceptre durum wheat was grown in pots with treatments of 0, 50, 100, 200, 400, and 800 g N as urea in a fine sandy loam soil. After the experiment it was observed that a significant in the plant cadmium concentrations as the nitrogen rte was increased to 800 g Mitchell *et al.* (2010). Another experiment was conducted with three N-fertilizers with different levels of NO^{-3} and NH^{+4} in a pot experiment to see how they affected the extractability of soil Cd in 1M ammonium acetate at pH 7 and the uptake of native and added Cd by winter rape (*Brassica napus* L. var. oleifera Metzger). In that case also Cd was taken up to a larger extent from the sand in both trials than from the clay. An increase in fertiliser dose often resulted in a rise in soil-Cd levels and plant Cd concentrations, Erikson (2010). Keeping above observation in mind a greenhouse pot culture experiment was conducted to evaluate the effect of nitrogenous fertilizer on cadmium uptake by wheat crop in an Inceptisol of Varanasi District, Uttar Pradesh.

Materials and Methods

The pot experiment was conducted to study the Growth, yield and cadmium accumulation in wheat crop (*Triticum aestivum* L.) as influenced by nitrogenous fertilizer in an Inceptisol of Varanasi, India during rabi season of 2019, in the net house of Department of Soil science and Agricultural Chemistry, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, U.P. Soil was collected from University Agricultural Farm, Banaras Hindu University for filling of earthen pots. Then soil was mixed properly and then sieved properly (2 mm sieve) to avoid cloding and to get fine texture soil. After that soil was transferred into 5 kg earthen pots. To prepare 5 mg kg^{-1} solution at first I have prepared 1000 ppm cadmium chloride stock solution. It was prepared by adding 2.036 g of cadmium chloride in 1litre of deionized water. It was made a solution of 1000 ppm $CdCl_2$ stock solution. From this stock solution the 5 mg kg^{-1} and 10 mg kg^{-1} concentration solutions were made. Four different standard doses of nitrogenous fertilizers (Urea) (0, 60, 120, 180 kg/ha) were used in the pots. In experiment, there were total twenty four pots (8 treatments and 3 replications). The doses of urea were applied in the pots with the application of 5 mg kg^{-1} and 10 mg kg^{-1} $CdCl_2$ solution separately. Other fertilizers like SSP and MOP were used 0.9375 g and 0.25 g respectively for all twenty four pots. The soil in each pot was then irrigated with tap water and pots were maintained at field capacity moisture for starting few days. Pots were watered daily with required amount of water on weight basis to maintain field capacity. Healthy seeds of wheat variety were surface sterilized with 0.5 % (V/V) sodium hypochlorite for 15 min and then rinsed 2-3 times with deionized water. Then the seeds were soaked overnight to germinate properly. On the day of sowing, at first light application of water was given in each pot to provide necessary moisture for germination of the seeds. 10-12 seeds per pot were sown to avoid germination failure and after the establishment of seedlings, thinning was done to retain only 5 healthy plants of nearly equal size in each pot. Four sets of pots with three pots (each pot with 5 plants) in each set were maintained. Crop was harvested at a single

time on 21.04.2020. After harvesting, samples were washed with tap water followed by dilute HCl (0.1N) and finally rinsed with distilled water. Plant samples were dried in hot air oven at 65±2 ^{o}C. After that dried plant samples were ground and used for subsequent chemical analysis. The spikes of the samples were separated from the plant and placed them in a different envelope for counting and to get the yield properly.

Results and Discussion

Plant height

The maximum plant hight was observed 29.73 cm at 30DAS, 51.4cm at 60DAS and 62.13 cm at 90 DAS at 5 mg kg^{-1} cadmium concentration. In case of 10 mg kg^{-1} cadmium concentration the highest plant height was found 30.33 cm at 30 DAS, 57.33 cm at 60DAS and 71.66 cm at 90 DAS. After comparing the each treatment it was found that at 5 mg kg^{-1} cadmium concentration T_4(@180 kg ha^{-1}) was found significantly superior over T_1 (control), T_2(@60 kg ha^{-1}) and T_3(@ 120 kg ha^{-1}). In the case of 10 mg kg^{-1} the most significant treatment was found T_7 (@ 120 kg ha^{-1}) followed by T_5 (N_2@ 0 kg ha^{-1}), T_6 (@ 60 kg ha^{-1}) and T_8 (@180 kg ha^{-1}).

Chlorophyll content

Results on chlorophyll content revealed that, the chlorophyll content was increased with nitrogen application. The highest chlorophyll content at 5 mg kg^{-1} cadmium concentration was 45.21, 41.33 and 48.66 respectively at 30, 60 and 90 DAS. In case of 10 mg kg^{-1} cadmium concentration the highest chlorophyll content was found 45.36, 46.63 and 48.70 at 30, 60 and 90 DAS. After the observation it was found that at 5 mg kg^{-1} cadmium concentration the most significant treatment was T_4(N_2@ 180 kg ha^{-1}) and at 60DAS it was T_3(N_2@ 120 kg ha^{-1}) which shown highest chlorophyll content than other treatments. Similar result was observed in case of 10 mg kg^{-1} cadmium concentration. The highest chlorophyll content was found in T_8 (N_2@ 180 kg ha^{-1}) at 30, 60 and 90DAS plants followed by T_5 (N_2@ 0 kg ha^{-1}), T_6 (N_2@ 60 kg ha^{-1}) and T_7 (N_2@ 120 kg ha^{-1}).

Spike length

Spike length is one of the important components for crop because it will help to estimate the yield attributes of that particular crop. The details of spike length are depicted in table. From the experiment it was observed that the spike length of the plant varied between (8.35-11.33), (9.06-13.12), (10.8-13.80) cm at 60, 90 and 120 DAS respectively at 5 mg kg^{-1} cadmium ion concentration. In the case of 10 mg kg^{-1} cadmium ion concentration the spike length ranges between (10.8-14.26), (13.12-14.11) and (13.80-15.00) cm at 60,90 and 120 DAS respectively. The maximum spike length, i.e. 11.33 cm, 13.12 and 13.80 cm were observed in T_4(N_2@ 180kg ha^{-1}) at 60, 90 and 120 DAS plants at 5 mg kg^{-1} cadmium ion concentration. For 10 mg kg^{-1} cadmium concentration the maximum length was observed at T_8 (N_2@180 kg ha^{-1}) for both the 60, 120 and 180 DAS. The maximum lengths in that case were 14.26, 14.11 and 15.00 cm. So from the above result it was cleared that the T_4 (N_2@180 kg ha^{-1}) was more significant than the T_1 (control), T_2 (N_2@60kg ha^{-1}) and T_3 (N_2@120kg ha^{-1}) at 5mg kg^{-1} cadmium concentration. And at 10 mg kg^{-1} cadmium concentration the T8 was more significant than T_5 (N_2@ 0 kg ha^{-1}), T_6 (N_2@ 60 kg ha^{-1}) and T_7 (N_2@ 120 kg ha^{-1}) respectively.

Tillers/plant

Tillers/plant is important yield attributes for yield measurement of wheat crop. The range of tillers was between (2-4) at 5mg kg^{1} and 10 mg kg^{-1} cadmium concentration. The highest numbers of tillers were with the T_4 and T_8 at 5 mg kg^{-1} and 10 mg kg^{-1} cadmium respectively. So, from the above result it was cleared that the most significant treatment was T_4 (N_2@ 180 kg ha^{-1}) at 5 mg kg^{-1} cadmium concentration other than T_1(N_2@ 0kg ha^{-1}), T_2 (N_2@ 60 kg ha^{-1}) and T_3 (N_2@ 120 kg ha^{-1}) respectively and T_8 (N_2@ 180 kg ha^{-1}) at 10 mg kg^{-1} cadmium concentration other than T_5 (N_2@ 0 kg ha^{-1}), T_6 (N_2@ 60 kg ha^{-1}) and T_7 (N_2@ 120 kg ha^{-1}) respectively.

Number of grains per year or spikes

The grain per year or spike was range between (32.66-52.66) at 5 mg kg^{-1} cadmium concentration. In case of 10 mg kg^{-1} cadmium concentration the range was between (38.00- 51.33). The maximum grain per year (52.66) was found in T_4 at 5 mg kg^{-1} cadmium concentration. At 10 mg kg^{-1} cadmium concentration the maximum grain per year was 51.33 in T8. So, at 5 mg kg^{-1} cadmium concentration more significant with T_4 (N_2@ 180 kg ha^{-1}) followed by T_1 (N_2@ 0 kg ha^{-1}), T_2 (N_2@ 60 kg ha^{-1}) and T_3 (N_2@ 120 kg ha^{-1}). At 10 mg kg^{-1} cadmium concentration T_8 (N_2@ 180 kg ha^{-1}) was found significantly superior over T_5 (N_2@ 0

kg ha^{-1}), T_6 (N_2@ 60 kg ha^{-1}) and T_7(N_2@ 120 kg ha^{-1}).

Yield/pot

It is cleared from the data (Table 1) indicated that the increasing level of nitrogenous fertilizer had also sown significantly increase in grain yield of wheat. The range of yield at 5 mg kg^{-1} cadmium was between (11.73-15.70) g/pot. At 10 mg kg^{-1} cadmium concentration the range of yield was between (12.66-16.60) g/pot. Maximum grain yield was obtained from N_2@ 180 kg ha^{-1} dose of fertilizer in case of 5 mg kg^{-1} cadmium concentration, i.e. 15.70 g/pot. In case of 10 mg kg^{-1} nitrogen concentration the maximum grain yield was found from also N_2@ 180 kg ha^{-1} dose of fertilizer. It means that the T_4 (N_2@180kg ha^{-1}) treatment was more significant at 5mg kg $^{-1}$ cadmium concentration than T_1 (N_2@ 0 kg ha^{-1}), T_2 (N_2@60 kg ha^{-1}) and T_3 (N_2@120kg ha^{-1}). Similarly, at 10 mg kg^{-1} cadmium concentration the maximum yield got from the T_8 (N2@180kg ha^{-1}) and it was more significant than T_5 (N_2@ 0 kg ha^{-1}), T_6 (N2@60 kg ha^{-1}) and T_7 (N2@120kg ha^{-1}) respectively. At 5 mg kg^{-1} cdmium concentration, the N_2@180 kg ha^{-1} crop yield was increased by 11.7% from N_2@ 60 kg ha^{-1} and increased by 12.1! from N_2@ 120 kg ha^{-1} and at 10 mg kg^{-1} cadmium concentration the N_2@ 180 kg ha^{-1} was increased by 8.8% from N_2@ 60 kg ha^{-1} and from N_2@ 120 kg ha^{-1} respectively. The result presented in Table below.

Nutrient content, Cadmium uptake and quality

The main aim of experiment is to observe the weather effect of the nitrogen fertilizer application enhanced the cadmium uptake in wheat plant or it will inhibit the cadmium uptake. The maximum accumulation in straw was 0.0173 mg kg^{-1}for 5 mg kg^{-1} cadmium concentration in T_4 (N_2@ 180 kg ha^{-1}) and at 10 mg kg^{-1} cadmium concentration cadmium accumulation in straw was 0.0333 mg kg^{-1} in T_8 (N_2@ 180 kg ha^{-1}) plants. For root accumulation 0.633mg kg^{-1} was highest cadmium accumulation in T_4 (N_2@ 180 kg ha^{-1}) at 5 mg kg $^{-1}$ cadmium concentration and at 10 mg kg^{-1} cadmium concentration the root accumulation was highest in T_8 (N_2@ 180 kg ha^{-1}), i.e. 0.83 mg kg^{-1}. The maximum nitrogen concentration in straw was found in T_4 (N_2@ 180 kg ha^{-1}) at 5 mg kg^{-1} cadmium concentration, i.e. 0.7! and for 10 mg kg^{-1} cadmium concentration the highest value was found in T_8 (N_2@ 180 kg ha^{-1}) which was 0.8! in straws. From T_3 (N_2@ 120 kg ha^{-1}) to T_4 (N_2@ 180 kg ha^{-1}) it was increased by 40! and from T_7 (N_2@ 120 kg

Table 1. Effect of nitrogenous fertilizer and cadmium concentration on plant height, chlorophyll content, Spike length, tillers/plant, grain/ear, yield/pot, plant cadmium content

Treatments	Plant height (cm)			Chlorophyll content (SPAD)			Spike length (cm)			Tillers/ plant	Grain/ ear	Yield/ pot (g)	Cadmium uptake by Plant (mg kg^{-1})	
Cd level 5 ppm	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	60 DAS	90 DAS	120 DAS				Straw (mg/kg)	Root (mg/kg)
T1 (N_2@ 0 kg ha^{-1})	26.71	46.53	55.93	37.16	46.16	48.66	8.35	9.06	10.8	2	32.00	11.73	0.003	0.013
T2 (N_2@ 60 kg ha^{-1})	27.06	44.3	53.13	38.88	38.41	43.50	9.74	9.95	11.26	3	43.00	12.53	0.013	0.3
T3 (N_2@ 120 kg ha^{-1})	29.57	45.8	59.14	39.21	41.33	45.63	11.27	11.80	12.03	3	47.00	14.00	0.014	0.4
T4 (N_2@ 180 kg ha^{-1})	29.73	51.4	62.13	45.21	35.61	45.76	11.33	13.12	13.80	4	52.66	15.70	0.017	0.063
Cd level 10 ppm														
T5 (N_2@ 0 kg ha^{-1})	28.76	53.33	62.13	37.84	38.76	46.34	10.8	13.12	13.80	2	38.00	12.66	0.02	0.2
T6 (N_2@ 60 kg ha^{-1})	30.4	55.55	70.33	39.58	46.63	48.60	10.44	11.36	12.06	3	43.00	13.50	0.024	0.5
T7 (N_2@ 120 kg ha^{-1})	28.1	58.66	83.20	40.45	44.26	47.44	12.73	14.13	14.66	3	45.00	14.70	0.027	0.66
T8 (N_2@ 180 kg ha^{-1})	30.33	57.33	71.66	45.36	45.33	48.70	14.26	14.11	15.00	4	51.33	16.60	0.033	0.83
C.D. (0.05)	2.042	11.13	10.442	4.359	5.572	0.391	0.226	0.238	0.268	1.069	3.492	0.374	0.004	0.150
SE(m)	0.667	3.637	3.412	1.423	1.820	0.129	0.075	0.079	0.088	0.354	1.155	0.113	0.001	0.049

Table 2. Effect of different treatments on post-harvest soil properties

Treatment	pH	EC (dS/m)	Nitrogen (kg/ha)	Phosphorus (kg/ha)	Potassium (kg/ha)	Calcium Meq/100g	Magnesium Meq/100g
Cd level 5ppm							
T_1(N_2@ 0 kg ha^{-1})	6.4	0.4	361.66	14.83	126	2.83	19.06
T_2(N_2@ 60 kg ha^{-1})	6.8	0.3	433.00	14.00	137	2.76	21.4
T_3(N_2@ 120 kg ha^{-1})	6.4	0.4	466.66	21.33	149	2.83	17.30
T_4 (N_2@ 180 kg ha^{-1})	6.5	0.4	563.33	22.00	129	4.33	16.76
Cd level 10ppm							
T_5(N_2@ 0 kg ha^{-1})	6.7	0.5	322.00	17.66	150	2.63	20.83
T_6(N_2@ 60 kg ha^{-1})	6.8	0.5	422.66	19.00	153	4.26	19.26
T_7(N_2@ 120 kg ha^{-1})	6.4	0.6	444.33	20.33	151	2.93	19.73
T_8(N_2@ 180 kg ha^{-1})	6.6	0.6	528.33	23.66	130	2.63	18.23
C.D. (0.05)	0.143	0.151	33.393	2.613	9.134	0.242	1.280
SE(m)	0.047	0.050	11.04	0.864	3.021	0.079	0.418

ha^{-1}) to T_8 (N_2@ 180 kg ha^{-1}) it was increased by 33!. In case of grain, the highest nitrogen was found in T_4 (N_2@ 180 kg ha^{-1}) which was 1.03! at 5 mg kg^{-1} cadmium concentration and 1.3! at 10 mg kg^{-1} cadmium concentration in T_8 (N_2@ 180 kg ha^{-1}) in the grain. The most significant one among them was T_4 (N_2@ 180 kg ha^{-1}) at 5 mg kg^{-1} cadmium concentration and T_8 (N_2@ 180 kg ha^{-1}) at 10 mg kg^{-1} cadmium concentration. From T_3 (N_2@ 120 kg ha^{-1}) to T_4 (N_2@ 180 kg ha^{-1}) nitrogen percentage increased by 19.8! and from T_7 (N_2@ 120 kg ha^{-1}) to T_8 (N_2@ 180 kg ha^{-1}) it was increased by 18.1!. As the nitrogen is applied through urea, the ammonium ions from urea may be competing with the Cd ions for soil absorption sites, when ammonium ion are in higher concentration, as a result Cd ions are more in soil solution.

Properties of post harvest soil

From the result it was cleared that the highest nitrogen found from T_4 (N_2@ 180 kg ha^{-1}), i.e. 563.33kg ha^{-1} at 5 mg kg^{-1} cadmium concentration and at 10 mg kg^{-1} cadmium concentration the highest amount was in T_8, i.e. 528.33 kg ha^{-1} than the other treatments. The highest concentration of phosphorus in the soil was 22 kg ha^{-1} in T_4 (N_2@ 180 kg ha^{-1}) at 5 mg kg^{-1} cadmium concentration and at 10 mg kg^{-1} cadmium concentration the maximum phosphorus concentration was 23.66 kg ha^{-1} in T_8 (N_2@ 180 kg ha^{-1}) treatment. So, for phosphorus concentration in soil solution, the most significant one was T_4 (N_2@ 180 kg ha^{-1}) at 5 mg kg^{-1} cadmium concentration. At 10 mg kg^{-1} cadmium concentration the most significant was T_8 (N_2@ 180 kg ha^{-1}. The maximum potassium concentration was (149 kg ha^{-1}) found in T_3 (N_2@ 120 kg ha^{-1}) other than T_1 (N_2@ 0 kg ha^{-1}), T_2 (N_2@ 60 kg ha^{-1}) and T_4 (N_2@ 180 kg ha^{-1}) at 5 mg kg^{-1} cadmium concentration and at 10 mg kg^{-1} cadmium concentration the maximum (153 kg ha^{-1}) limit was with T_6 (N_2@ 60 kg ha^{-1}). The highest calcium content was found in T_4 (N_2@ 180 kg ha^{-1}), i.e.4.33 (Milliequivalent/100g of soil) at 5 mg kg^{-1} cadmium concentration. The highest calcium concentration in case of 10 mg kg^{-1} cadmium concentration was T_6 (N_2@ 60 kg ha^{-1}) i.e.4.26 Milliequivalent/100g of soil. The highest magnesium content was found in T_2 (N_2@ 60 kg ha^{-1}) i.e.21.4 (Milliequivalent/100g of soil) at 5 mg kg^{-1} cadmium concentration. The highest magnesium concentration at 10 mg kg^{-1} cadmium concentration was T_5 (N_2@ 0 kg ha^{-1}), i.e.20.83 Milliequivalent/100g of soil. The highest pH was found in T_2 (N_2@ 60 kg ha^{-1}) which was 6.8 at 5 mg kg^{-1} cadmium concentration. While at 10 mg kg^{-1} cadmium concentration the highest pH was also 6.8 in T6. The highest EC was found in T_1 (N_2@ 0 kg ha^{-1}), T_3 (N_2@ 120 kg ha^{-1}) and T_4 (N_2@ 180 kg ha^{-1}) which was 0.4 ds/m at 5 mg kg^{-1} cadmium concentration other than T_2 (N_2@ 60 kg ha^{-1}). At 10 mg kg^{-1} cadmium concentration the highest EC was 0.6 ds/m in T_7 (N_2@ 120 kg ha^{-1}) and T_8 (N_2@ 180 kg ha^{-1}).

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