Vanadium inhibition capacity on nutrients and heavy metal uptake by *Cucumis Sativus*

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Abstract: Pot experiments were conducted to investigate the inhibition capacity of vanadium on nutrients and heavy metals uptake by *Cucumis Sativus* (Cucumber). The concentration of the nutrients and heavy metals were determined using standard methods. The results revealed that as the concentration of NH_4VO_3 increases the uptake of the nutrients and heavy metals decreases. The Percentage uptake ranged from 13.00 to 61.70%, N; 18.30 to 46.50%, P; 24.30 to 54.30%, Zn; 8.90 to 43.40 %, K; 8.80 to 33.40 %, Fe; 4.30 to 23.51 %, Pb and 20.50 to 52.00 %, Cd. Uptake of the nutrients and heavy metals was high in the non-vanadium treated (control) soil sample with values, 61.70%, N; 46.50%, P; 43.40%, K; 33.40%, Fe; 54.30%, Zn; 23.51%, Pb; and 52.00%, Cd. Percentage uptake decreases as the concentrations of vanadium increases. At 30 Mg/L vanadium, the nutrients decreased as follows 13.00%, N; 18.30%, P; 24.30%, Zn; 8.90%, K; 8.80%, Fe; 4.30%, Pb and 20.50%, Cd. There is antagonist effect on the heavy metals, Pb and Cd uptake could be especially relevant since the metals are toxic.

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1. Introduction

Ammonium metavandate is the inorganic compound with the formula NH_4VO_3 (Bauer, et al., 2005). Vandates can behave as structural mimics of phosphates and in this way they exhibit biological activity (Korbecki et al.,2012, Crans and Chatterjee, 2013). When material containing ammonium metavandate is rosted, vanadium pentaoxide is produced.

$$2\ NH_4VO_3 \rightarrow V_2O_5 + 2\ NH_3 + H_2O \text{……..(i).}$$

Natural source of atmospheric vanadium include continental dust, marine aerosols, (sea salt sprays) and volcanic emission. Vanadate readily forms complexes with ligands containing oxygen, nitrogen and sulfur donor functionalities (Nriagu, 1998). Vanadium is widely dispersed in the environment in several ways including the leaching of rocks, the combustion of coal or petroleum products, the contamination from the use of fertilizers, and residual slags from the steel industrial, as a result, vanadium has been increasingly released into the soil, water and atmosphere (Ringelband and Hehl, 2000). Weak complexes form between vanadate and carbonate, phosphate, arsenate, chromate and similar ligands. In aqueous solution, both vanadate undergo a number of hydrolytic and self-condensation reactions which distinguish the aqueous chemistry.

Vanadium dissolved in water is present almost exclusively in the pentavalent form. Its concentration ranges from approximately 0.1 to 220 μg/L in fresh water and from 0.3 to 29 μg/L in sea water. The highest concentrations in fresh waters were recorded in the vicinity of metallurgical plants or downstream of large cities (Bauer *et al*., 2003). Anthropogenic sources account for only a small percentage of the dissolved vanadium reaching the oceans (Hope, 1994). Vanadium intake from food has been reasonably well established, based on the analysis of dietary items (Minoia *et al*., 1994) and total diets (Byrne & Kucera, 1991a). Considering consumption of about 500 g (dry mass) total diet, daily dietary vanadium intake in the general population has been estimated at 10–30 μg per person per day, although it can reach 70 μg per day in some countries (Byrne & Kucera, 1991a).

Vanadium compounds caused a several-fold increase in heparin-binding epidermal growth factor (HB-EGF) mRNA expression and protein in normal human bronchial epithelial cells and increased the release of HB-EGF mitogenic activity of these cells (Zhang et al., 2001a). Vanadium (V) is widely dispersed in the environment in several ways including the leaching of rocks, the combustion of coal or petroleum products, the contamination from the use of fertilizers, and residual slags from the steel industry. As a result, V has been increasingly released into the soil, water and atmosphere (Ringelband and Hehl, 2000). Vachirapatama *et al.* (2002) revealed that some phosphate fertilizers were contaminated with high concentrations of V (90-180 mg/kg). This may suggest that the use of these phosphate fertilizers may cause the V to become widely spread in soils, water and vegetables and it has potential effects to human and animal health. However, this study revealed the vanadium inhibition capacity on nutrients and heavy metal uptake by *Cucumis Sativus.*

2. Material and Methods

Sample collection and preparation

Pot experiments were conducted at room temperature conditions for a period of 28 days to study the effect of different concentrations of Vanadium application on uptake of plant nutrients (N, P, Zn, K, Fe) and heavy metals (Pb and Cd) from soil by *Cucumis Sativus* in the department of pure and Industrial Chemistry, University of Port Harcourt, Nigeria. A plot of farmland in University of Port Harcourt Research farm was randomly sampled from the surface (0 - 10 cm) and seeds of *Cucumis Sativus* (Cucumber) samples were collected from National Root Crop Research Institute, Umudike in the month of March, 2016.

Sample treatment and planting

Different vanadium concentration (0 ppm (control), 10 ppm, 15 ppm, 20 ppm and 40 ppm) was made from ammonium metavandate (NH_4VO_3) salts using de-ionized water. The collected soil samples were analyzed for nutrients and heavy metals before treatment. The soil (500 g) was slowly mixed thoroughly with the different concentrations (200 ml) of solution using a glass rod and left to equilibrate for one day. Five (5) seeds of cucumber was sown in 40 cm diameter porous pots filled with 200g of treated soil which has some percentage of clay, loam and silt with pH range of 6.81-7.22 at room temperature and the porous pots were watered with distilled water as described by (Houshmandfar Tehrani, 2008) for a period of 28 days. After which the plant were removed and the contents of soil were determined according to (Jackson, 1973).

3. Results and discussion

Table 1: Concentration (mg/L) levels of the nutrients and heavy metals before treatment

P	N	Fe	Zn	K	Cd	Pb
43.40	33.00	4831.60	152.00	258.80	0.40	3.40
49.10	34.30	5013.40	159.20	309.50	0.34	1.06
	48.20	3934.00	169.50	224.10	0.60	1.30
38.30	35.00	3843.00	140.00	201.40	0.80	2.50
34.60	29.70	5401.60	180.10	317.50	0.40	1.80
33.70						

Table 2: Concentration (mg/L) levels of the nutrients and heavy metals after treatment

Mg/L NH_4VO_3	N	P	Zn	K	Fe	Pb	Cd
0	12.64	23.22	69.46	146.48	3217.85	2.60	0.192
10	19.77	35.30	77.37	185.39	3980.64	0.84	0.224
15	33.89	30.30	113.40	168.35	3371.44	1.05	0.422
20	26.74	27.65	97.70	170.79	3420.21	0.05	0.616
40	25.84	29.32	136.34	289.24	4926.31	1.03	0.318

Table 3: Vanadium inhibition capacity on nutrients and heavy metal uptake by plant.

% $NH_4(VO_3)$	N	P	Zn	K	Fe	Pb	Cd
0	61.70	46.50	54.30	43.40	33.40	23.51	52.00
10	42.40	28.10	51.40	40.10	20.60	20.75	34.10
15	29.70	20.90	33.10	24.70	14.30	19.23	29.70
20	23.60	20.10	30.20	15.20	11.00	9.80	23.00
40	13.00	18.30	24.30	8.90	8.80	4.30	20.50

The percentage uptake of nutrient and heavy metal by edible plant (*Cucumis Sativus*) from soil using different concentrations of vanadium compound (NH_4VO_3) was presented in table 3. The Percentage uptake ranged from 13.00 to 61.70 %, N; 18.30 to 46.50 %, P; 24.30 to 54.30 %, Zn; 8.90 to 43.40 %, K; 8.80 to 33.40 %, Fe; 4.30 to 23.51 %, Pb and 20.50 to 52.00 %, Cd. Plants take up essential elements from the soil through their roots and from the air through their leaves. Nutrient uptake in the soil is achieved by cation exchange, wherein root hairs pump hydrogen ions (H+) into the soil through proton pumps. These hydrogen ions displace cations attached to negatively charged soil particles so that the cations are available for uptake by the root.

Uptake of the nutrients and heavy metals was high in the non-vanadium treated (control) soil sample with values, 61.70 %, N; 46.50 %, P; 43.40 %, K; 33.40 %, Fe; 54.30 %, Zn; 23.51 %, Pb; and 52.00 %, Cd. Percentage uptake decreases as the concentrations of vanadium increases. The enzyme phosphatase, which is mainly released by soil microorganisms to mineralize organic phosphorous, has shown reduced activity as a result of vanadium addition (Tyler, 1976). Vanadium is mainly accumulated in the roots (Yang et al., 2011). This is probably due to the reduction of vanadate (v) to vanadyl (iv) during root uptake. Nitrification and nitrogen mineralization can be inhibited by vanadium addition (Liang and Tabatabai, 1978). In natural soils, the metal (hydr)oxide content is considered one of the most important properties for vanadium sorption (Gabler et al., 2009).

Metal toxicity and inhibitive efficiency are important factors to be considered when examining plant uptake of nutrients. The effect of substances such as nickel on plants uptake of nutrients is dependent on the amount or concentration of such substance taken up by plant in the environment. Observed that decrease in plants uptake of nutrient, may be attributed to accumulation on the plants body (seed) thus weakening the uptake control mechanism. This inhibition of nutrients uptake is also attributed to bonding of negative (soil) and positive (metal) charge because metal binds with hydroxyl (OH-), and carboxyl group (COOH) and phenolic groups of soil. The physiological effect of metals on plants cellular interactions is also considered as probable contributor to nutrient inhibition (Houshmandfar and Moraghebi, 2011).

Iron and aluminum (hydr) oxides determine the mobility of V in soils and water (Naeem et al., 2007; Wallstedt et al., 2010) and therefore its fate. Vanadium can form strong complexes with organic matter, and in the presence of organic substances, V (V) may be reduced to V (IV), especially at low pH (Lu et al., 1998). Vanadate is absorbed by plant tissues (Bowman 1983; Ullrich-Eberius et al., 1989) and can inhibit plasma membrane hydrogen (H+)-translocating ATPase (Vara and Serrano 1982), which is known to play an important role in nutrient element uptake by plant cells.

4. Conclusions

Vanadium did not retard the growth of *Cucumis Sativus* as the concentration increases from 0 to 40 Mg/L. Vanadium negatively impacts the nutritional quality of *Cucumis Sativus* regarding the nutrients (Fe, N, P, and K) content since it inhibit the uptake of these nutrients from the soil. However, its antagonist effect on Cd and Pb uptake could be especially relevant where cucumber is grown on soils contaminated with such metals.

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