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Growth and Cadmium Content in Lettuce and Swiss Chard Plants as Affected by Zinc, Rock Phosphate and Organic Matter Applications

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POT experiments were performed in the North Carolina State University greenhouse using Phosphogypsum/clay tailings from the Potash Corporation of Saskatchewan (PCS) phosphate mine site which contained about 2:1 Zn:Cd ratio. In the first season, lettuce plants (*Lactuca sativa var.* Parris Island) were growen on the PCS soil with increased Zn content (2:1, 5:1, 25:1, 50:1, 75:1, 100:1, 125:1, 150:1 and 200:1 Zn:Cd ratio) and with four levels of rock phosphate (0.5%, 1%, 2.5% and 5%). The residual effect of these treatments were determined by growing swiss chard plants *(Beta vulgaris var.* Lucullus) on the same treated soils. Five Zn:Cd ratios (2:1, 25:1, 100:1, 150:1 and 200:1) were used with the application of 1or 3% of composted leaves to detrmine the effect of organic material along with Zn applications on swiss chard uptake of Cd. The obtained resuls indicated that Cd concentration in lettuce plants was significantly and gradually decreased from 69.95 ppm to 29.64 ppm in the plants growen on the original PCS soil and the soil treated with 50:1 Zn:Cd ratios, respectively. Whereas the decrease of Cd concentrations in swiss chard plants was from 40.41 ppm to 32.11 ppm in plants growen on the original PCS soil and the soil with 25:1 Zn:Cd ratio, respectively. Compared with the original PCS soil, the application of 5% rock phosphate significantly decreased Cd uptake from 19.00 ppm to 12.59 ppm and from 35.17 ppm to 28.19 ppm in Lettuce and Swiss Chard plants, respectively. The application of 3% composted leaves generally decreased the amounts of Cd uptake by swiss chard plants. The goal of this study was to decrease the plant uptake of Cd by increasing Zn content with and without the application of organic material and also by rock phosphate application.

Keywords: Cadmium, Zinc, Rock Phosphate, Organic Material, lettuce, Swiss chard .

The harmful effects of Cadmium when entering the food chain in excess amounts is one of particular environmental concern. The distribution of Cd among various chemical forms is of importance with respect to its solubility, mobility and bioavailability (He and Singh, 1993). Differences in enzyme activity in plant stressed with high cadmium was cited by Hertsein and Jager (1986). In a test of 10 agronomic crops, Kuboi (1987) found that cadmium sensitivity to be directly linked to the botanical family and independent of soil pH. Levels of cadmium at which chlorosis appeared were 80 mg L^{-1} for Japanese radish, 10 mg L^{-1} for soybean and 100 mg L^{-1} Cd for pumpkin.

Phosphorus fertilizers contain cadmium (Cd) as a contaminant at levels varying from trace amounts to as high as 300 mg Cd kg^{-1} of dry product, and therefore represent a major source of Cd input into agricultural systems (Grant, 2011).

A common source of Cd contamination is phosphate mining, which leaves contaminated phosphogypsum/clay tailings (Sery *et al.,* 1996). Cadmium is a heavy metal present naturally in all soils and added annually as contaminant in phosphate fertilizers (Wang *et al*., 2011). Although the presence of Zn in P fertilizers may reduce Cd bioavailability, P fertilizer may itself restrict crop uptake of Zn, which would also serve to potentially increase Cd accumulation (Moraghan, 1984).

Similar geochemical and environmental properties are found in both Cd nd Zn which leads to interaction between them during plant uptake, transport from roots to the aerial parts, or accumulation in the edible parts (Das *et al.,* 1997). Although cadmium and zinc may be considered chemically similar elements because of their similar ionic structure and may influence each other in plant uptake and accumulation, but they play quiet different roles in the plant's metabolism. Zinc is a micronutrient, whereas Cd is toxic and ordinarily is found at very low concentrations in plants usually, Zn concentration is more than 100 times of Cd level (Chaney *et al*., 1999). Wang *et al.* (2011) mentioned that Cd actually absorbed by the root Zn transporter, so low supply of plant available Zn promots Cd accumulation by plants.

It is generally accepted that Zn status in soils and plants playes an important role in Cd accumulation in crop plants (Sarwar *et al*., 2010). Low plant available Zn in soil promots Cd uptake and also promots toxicity of Cd to animals which ingest plant products (Wang *et al.,* 2011). Antagonistic effects have been reported by some researchers (McLaughlin and Singh, 1999 and Long *et al.,* 2003) but syneregistic by others (Nan *et al*., 2002). In a pot investigatio, Zn suppressed Cd concentration of spinach shoots (Talatam and Parida, 2009).Great differences occur among species and even between different varieties of the same species (Grant and Bailey, 1997).

Organic matter plays an important part by reducing plant uptake of Cd from soils due to its high cation exchange capacity and complexing ability (He and Singh, 1993). Previous works reported that the addition of compost into the soils decreased the Cd concentration in rice (Sarkuman *et al.,* 1996). Talatam and Parida (2009) reported that organic manure can play a vital role in counteracting the harmful effects of excess Cd in soil. They found that spinach dry matter yield was inhanced with the application of farmyard manure by forming complexes with Cd resulting to the reduction of Cd concentration in soil.

This study focuses on soil from the Potash Corporation of Saskatchewan (PCS) phosphate mine in Lee Creek, North Carolina. To decrease the uptake of Cd by *Lactuca sativa var.* Parris Island (lettuce) and *Beta vulgaris var.* Lucullus (swiss chard), a possible hyper-accumulating plants using Zn , composted leaves and rock phosphate applications.

Material and Methods

The PCS Phosphate Aurora facility is located at Lee Creek in Beaufort County, North Carolina, USA. The ore zone is 12 m thick and is made up of phosphate sand (35%), fine quartz (45%), clay, and silt (Andrews, 2003). Phosphate is removed from the ore where the phosphate fraction is separated from the clay and sand. The acidulation process combines sulfuric acid and the ore to produce phosphoric acid and a by-product of phosphogypsum/clay tailings blend (Markland, 1996). Two-thirds of Cd is retained by the phosphoric acid and the remaining one-third is in the byproduct phosphogypsum/clay tailings blend (Wescott, 1994).

The two by-products of this process that form the blend used in this study are phosphogypsum and clay tailings in a ratio of 2:1 were blended together in an attempt to reclame the PSC Phosphate Aurora facility. The mining site is filled with this blend material. The elimination of the clay tailings settling ponds and the elimination of the phosphogypsum/clay tailings piles are two benefits of this method (Broome *et al*., 1994). Blend materials at the Aurora facility contain much higher Cd concentrations than that occur naturally in soils, and thus, there is a much greater chance of plant uptake of Cd from such soils.

Greenhouse studies were conducted to study the effects of Zn, rock phosphate and organic matter on Cd uptake by lettuce and swiss chard plants. Phosphogypsum/clay tailings from the PCS phosphate mine site were amended with Zn salts to obtain 10 different Zn:Cd concentration ratios (half of the Zn was added as zinc sulfate and half as zinc carbonate) and four rock phosphate (RP) treatments. Additionally, up to 3% organic matter were used to amend the soil in conjunction with Zn.

Total soluble salts were determined by measuring the electrical conductivity in the 1:2 soil:water extract (Dellavalla, 1992). Soil pH was measured in 1:1 soil: water suspensions using a glass electrode (Jackson, 1973). Mechanical analysis was carried out using the pipette method . The blend samples were analyzed for Olsen P extraction . Cadmium and Zin were extracted using the DTPA method according to Lindsay and Norvell (1978) and then measured by Flame Atomic Absorption Spectrophotometer (AAS). The results of particle size analysis indicated that the texture of the original PCS soil (control) is a silt loam predominantly consisting of 66% silt , 26% sand and 8% clay with pH 7.3, EC 1.99, Olsen P 872 ppm, DTPA extractable Cd 4.54 ppm and DTPA extractable Zn 7.95 ppm with a Zn:Cd ratio of 1.75 (Table1).

TABLE 1. DTPA extractable Cd and Zn, pH and EC in the blend treatments.

Treatment (Zn:Cd)	pH (1:1)	EC (dS m^{-1}) (1:2)	Cd (ppm)	Zn (ppm)	Zn/Cd
2:1 (Control)	7.03	1.99	4.54	7.95	1.75
15:1	6.83	1.79	4.50	31.35	6.96
25:1	6.86	1.73	4.33	78.76	18.20
100:1	6.94	1.72	3.43	200.16	58.39
150:1	6.95	1.56	3.61	303.87	84.27
200:1	6.94	1.55	3.88	478.19	123.31
0.5 % RP	7.04	1.66	3.73	10.11	2.71
2.5%RP	7.21	1.54	3.61	7.49	2.08
1% OM 2:1	7.04	1.59	3.49	8.63	2.47
1% OM 100:1	6.98	1.65	3.78	208.15	55.08
1% OM 200:1	6.94	1.55	3.53	705.61	200.00
3% OM 2:1	6.88	1.52	3.49	11.28	3.23
3% OM 100:1	6.86	1.54	4.05	261.86	64.67
3% OM 200:1	6.83	1.51	4.24	864.03	203.06

In the first season, Lettuce plants (*Lactuca sativa var.* Parris Island) were growen on the PCS soils with increasing Zn:Cd ratios (2:1, 5:1, 25:1, 50:1, 75:1, 100:1, 125:1, 150:1 and 200:1) by adding half of the Zn amount as Zn sulfate and half as Zn carbonateand. Four rates of rock phosphate were also used (0.5%, 1%, 2.5% and 5% RP).

In the second season, the residual effect of these treatments were determined by growing Swiss Chard plants *(Beta vulgaris var.* Lucullus) on the same treated soil. Five Zn:Cd ratios (2:1, 25:1, 100:1, 150:1 and 200:1) were used with the application of 1or 3% composted leaves to detrmine the effect of organic mater application along with Zn treatments on swiss chard uptake of Cd.

Ten Lettuce seeds *(Lactuca sativa var.* Parris Island), in the first season, and ten swiss chard seeds (*Beta vulgaris var.* Lucullus), in the second season were planted in each pot containing 1 kg treated and air dry amended phosphogypsum/clay tailings blend. Each treatment contained three replicates. The pots were randomized and arranged in a serpentine pattern in the greenhouse of North Carolina State University. Lettuce plants were hand watered with prescribed volumes of deionized water on a daily to bi-daily basis to bring the soil water content of the pots to ~70% field capacity; swiss chard plants were watered with a drip irrigation system. Approximately two weeks after germination the plants were thinned to five plants per pot. Potassium nitrate (0.06 g/ pot) was added as a nitrogen source for the plants.The plants were harvested six weeks after planting.

The plants were collected, washed with deionized water, oven dried at 70 °C and weighed to determine the plant dry biomass. Leaf tissue was ground by hand and digested in digestion tubes with 5 mL concentrated HNO_3 at room temperature overnight, in the second day the samples were heated to 130 °C for two hours until digestion was complete. Cd and Zn concentrations were then measured using a Flame Atomic Absorption Spectrophotometer (AAS).

Results and Discussion

1. Effect of Zn and rock phosphate application on lettuce dry weigh and Cd and Zn content

Growth of Lettuce plants in the phosphogypsum/clay tailings blend was stunted (Table 2), as observed in earlier studies (Markland, 1996). This stunting may be due to the Cd toxicity and/or high salt content of the soil that ranged from 1.51 to 1.99 dS m^{-1} in 1:2 soil:water extract (Table 1) which is consedered as saline soil (from 1.21 to 1.60 dS m^{-1}) or strongly saline (1.61 – 3.20 dS m^{-1}) in 1:2 soil:water extract, according to Dellavalla (1992). Although the differences in dry weight were very small, some of Zn applications significantly decreased lettuce biomass compared with the biomass of the control especially with 15:1 and 25:1 Zn:Cd ratio. Increasing RP percentage gradually and significantly decreased lettuce dry weight. The marked abnormality low biomass produced may elevate the concentration of metals in plant tissue, affecting the results of uptake studies which indicates that uptake results should not be intrepred as absolut number. Moustakas *et al.* (2011) found that although considerable Cd concentrations were found in Marigold (*Calendula officinalis* L.), no growth depression was detected.

TABLE 2. Effects of Zn (Zn:Cd ratio) and rock phosphate (RP) applications on lettuce growth and metal uptake.

Zn:Cd ratio/ RP application	Cd conc. (ppm)	Zn conc. (ppm)	Zn/Cd	Dry weight (g)	Cd uptake (ppm)	Zn uptake (ppm)
2:1(control)	69.95	87.2	1.25	0.27	19.00	23.7
5:1	52.19	116.8	2.24	0.27	13.88	31.0
15:1	48.31	128.8	2.67	0.21	10.04	26. 8
25:1	36.19	166.3	4.60	0.21	7.70	35.4
50:1	29.64	210.1	7.09	0.25	7.46	52.9
75:1	33.09	299.3	9.05	0.26	8.66	78.4
100:1	36.68	387.6	10.60	0.25	8.98	95.0
125:1	36.79	447.2	12.16	0.26	9.41	114.4
150:1	36.76	499.3	13.58	0.27	10.03	136.3
200:1	36.99	630.1	17.03	0.28	10.26	174.8
L.S.d 0.05	**2.01**	**19.3**	**0.40**	**0.02**	**1.38**	**4.3**
2:1(control)	69.95	87.2	1.25	0.27	19.00	23.7
0.5% RP	69.91	79.6	1.45	0.22	15.29	17.4
1% RP	71.44	78.1	1.09	0.19	13.40	14.7
2.5% RP	71.49	77.4	1.08	0.19	13.26	14.4
5% RP	74.08	82.5	1.11	0.17	12.59	14.0
L.S.d 0.05	**2.33**	**6.6**	**0.08**	**0.02**	**1.92**	**2.5**

Lettuce plants took up high concentrations of both Cd and Zn that exceeded the maximum allowable limits with some treatments. Zinc concentration and uptake was gradually increased from 87.17 ppm and 23.68 ppm (with the control blend, 2:1), respectively, to 630.07 and 174.82 ppm (with the maximum Zn/Cd ratio, 200:1) (Fig. 1). Maximum tolerable levels for Zn in agricultural soils proposed in various countries ranged from 150 to 300 mg Zn kg-1 (Kabata-Pendias and Pendias, 1992).

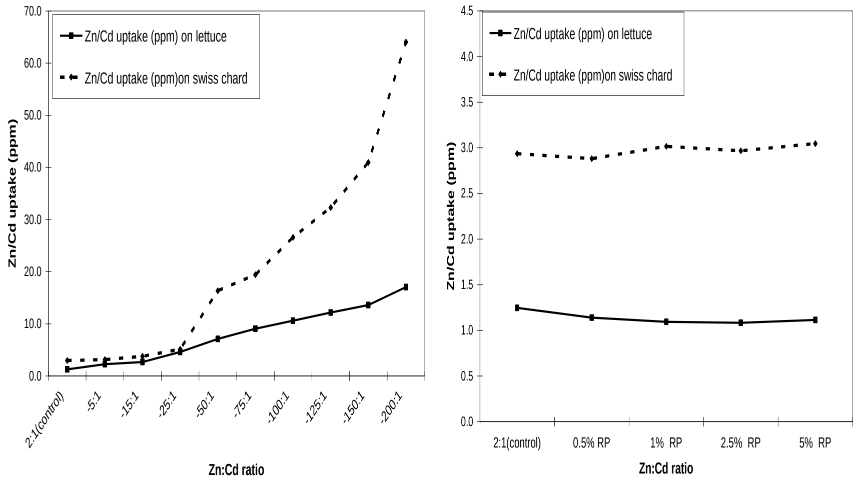

Fig. 1. Effect of Zn:Cd ratio in soil and RP application on Zn:Cd ratio in lettuce and swiss chard plants.

Although all Zn applications decreased Cd content in lettuce plants, cadmium concentrations were much higher than the maximum tolerable levels (from 1.6 to 3ppm Cd) mention by Kabata-Pendias and Pendias (1992). Increasing Zn concentration appears to significantly and gradually reduce the amount of Cd concentration by plants at Zn:Cd ratios equal to or below 50:1. Cadmium concentration in lettuce was 57.6% decreased when Zn:Cd ratio reached 50:1. The interaction of Cd with Zn in plants is based on the substitution of Cd with Zn and decrease in Cd below its phytotoxic concentration in tissues (Kabata-Pendias and Pendias, 1989).

Above Zn:Cd ratio of 50:1, the Cd concentration slightly increased from 29.64 ppm at Cd:Zn 50:1 to 36.99 ppm at Cd:Zn 200:1 which was independent of the increasing of Zn concentration in both blend and plants. Long *et al.* (2003) found an antagonestic realtionship between Zn and Cd, while Nan *et al.* (2002) found the realation to be sinergistic. The results from this experiment provide evidence that lettuce has the ability to accumulate Cd in the leaf tissue when growen on phosphogypsum/clay tailings blend and may be used as a clean up plant for such soils. Increasing rock phosphate concentrations up to 5% resulted in 37.5% reduction in lettuce biomass, compared with the control (Table 2).

The reduction of biomass may be due to the toxic amounts of absorbed Cd which reached the highest concentration (74.08 ppm) in all tested lettuce plants. The increased application of rock phosphate (RP) from 0.5% to 5%, to the blend gradually increased Cd concentrations in lettuce tissue from 69.91ppm to 74.08 ppm, respectively. The observed increase of Cd may be due to the indirect application of this metal with the application of RP and/ or the low Zn:Cd ratio in the blend (2:1) that improve Cd absorption by plants according to Wang et al. (2011). The concentrations of Zn gradually and significantly decrease from 87.2 in the control treatment to 77.4 ppm when the rock phosphate application increased up to 2.5%. This may be a possible result from the rock phosphate suppressing the bioavailability of Zn. Numerous studies have demonstrated that P fertilization causes a reduction of Zn concentrations in plants, which is possibly due to P-Zn interactions in soil (Lambert *et al*., 2007), interference with Zn uptake, reduced translocation of Zn from roots to shoots, dilution effects from a large P yield response, P toxicity resulting from restricted Zn supply, or a plant metabolic disorder (Cakmak and Marschner, 1986 and Cakmak & Marschner, 1987). The application of 5% RP increased Zn concentration up to 82.7 ppm. This effect may be the result of the reduced biomass of plants due to Cd toxicity at higher concentrations of rock phosphate. Clarkson and Lutge (1989) reported that Cd damages the biomembrane and cause enzymatic changes and possible interaction with macro and micro-elements leads to the phytotoxicity of this element.

2. *Residual effect of Zn and rock phosphate application on swiss chard growth and Cd and Zn content*

As with lettuce, growth of swiss chard in the phosphogypsum/clay tailings blend was stunted (Table 3). In addition, there was high degree of vaiablity in the growth of plants within a trial. The vaiability may have been due to inconsistencies in water distribition from the drip irrigation system. In their review of Cadmium Toxicity in Plants, Das *et al.* (1997) reported that the effect of elevated cadmium levels in soils are stunting and chlorosis of plants were the main visual symptoms.

Although Zn treatments had no specific treand on swiss chard dry weight, the highest Zn/Cd ratio (200/1) significantly decreased the dry wiegh 38.1% compared with the control. This reduction might be due to the toxicity of Zn that reached 3087 ppm in dry tessue, along with the high content of Cd (48.59 ppm).

Data trend for uptake of metals by swiss chard as a resedual effect of the treatments had some similarity with those of lettuce. The application of Zn up to a ratio of 25:1 Zn:Cd significantly decreased Cd content in swiss chard from 40.41 ppm (the control) to 32.10 ppm, similar trend was reported by Moustakas *et al.* (2011). They found that the concentration of Cd in Marigold plant (*Calendula officinalis* L.) leaves decreased significantly with increasing Zn application which might be due to the competitive transport and absorption interaction between these two ions. However, reverse trend was noticed in swiss chard with increasing the ratio to 150:1 Zn:Cd which gradually and significantly enhanced the concentration of Cd by 60.6% compared with the control. When Zn:Cd ratio was raised up to 200:1, Zn concentration reached 3087 ppm while Cd content was decreased by 25.1% compared with the previous Zn/Cd ratio (150:1 Zn:Cd ratio).

TABLE 3. Residual effects of Zn (Zn:Cd ratio) and rock phosphate (RP) applications on swiss chard growth and metal uptake.

Zn:Cd ratio/ RP rate (%)	Cd conc. (ppm)	Zn conc. (ppm)	Zn/Cd	Dry weight (g)	Cd uptake (ppm)	Zn uptake (ppm)
2:1(control)	40.41	118.8	2.94	0.87	35.17	103.1
5:1	38.35	119. 7	3.12	1.22	46.78	146.3
15:1	33.15	124.4	3.75	0.97	32.07	120.7
25:1	32.11	163.4	5.09	1.05	33.64	170.5
50:1	45.89	745.1	16.34	0.90	41.18	668.1
75:1	47.64	924.0	19.40	1.08	51.70	1003.5
100:1	53.30	1418.3	26.57	1.03	55.04	1455.1
125:1	62.67	2020.1	32.28	1.13	70.63	2283.9
150:1	64.91	2657.5	40.95	1.03	66.65	2722.7
200:1	48.59	3087.0	63.65	0.65	31.62	2009.4
L.S.d 0.05	**4.12**	**143.7**	**3.51**	**0.16**	**8.55**	**238.8**
2:1(control)	40.41	118.8	2.94	0.87	35.17	103.1
0.5% RP	41.95	120.6	2.88	0.91	38.08	109.5
1% RP	34.18	102.1	3.02	0.91	30.91	92.3
2.5% RP	33.90	100.5	2.97	0.90	30.66	90.9
5% RP	31.51	96.1	3.05	0.90	28.19	85.9
L.S.D 0.05	**4.26**	**12.2**	**n.s**	**n.s**	**4.09**	**11.1**

Both Zn and Cd contet were significantly decreased as residual effect of increasing rock phosphate application, while the dry weight was almost the same. As Zn competes with Cd for uptake and translocation by plants, Zn contamination in P fertilizers may actually reduce Cd accumulation in crops (Jiao *et al*., 2004).

Increasind Zn:Cd ratio in the soil significantly increased Zn:Cd ratio in both lettuce and swiss chard plants. The increase was higher in swiss chard plants (the residual effect) due to the less amounts of absorbed Cd (Fig. 1). On the other hand, the application of RP resulted in almost the same trend of Zn:Cd ratio in both plants with a stable amounts of Zn:Cd ratio in plant tessues.

3. Effect of Zn and composted leaf applications on swiss chard growth and Cd and Zn content

The main effect of composted leaf applications was highly significat with a reduction in both Cd concentration and dry weight from 44.34 ppm and 1.10 g with 1% application of OM to 38.65 ppm and 0.53 g with 3% application of OM, respectively (Table 4). The application of 3% OM significantly decreased swiss chard biomass with all Zn treatments compared with the same treatments with 1% OM with a graduall increase in dry weight with increasing Zn:Cd ratio up to 150:1. The Dry weight was decreased with the highest Zn:Cd ratio (200:1 Zn:Cd) due to Zn toxicity. The combined effect of farmyard manure and Zn reduce the Cd content more than the application of each separetly (Talatam and Parida, 2009). Both Zn concentration and Zn:Cd ratio were significantly increased with increasing OM level from 1362.2 ppm and 31.12 to 1427.5 ppm and 35.26, respectively. That was due to the decomposition of OM which released more available Zn to the plants. Due to its readily available binding sites, the addition of organic matter to metal containing soils decreases in metal activity in the soil solution (Das *et al.*, 1997). With organic matter and clays present in the soil, low molecular weight metal chelates are formed which keep free metal activity low.

TABLE 4. Effects of Zn (Zn:Cd ratio) and organic material (OM) applications on swiss chard growth and metal uptake.

OM Treatments (%)	Zn:Cd Ratio	Cd conc. (ppm)	Zn conc. (ppm)	Zn/Cd	Dry weight (g)	Cd uptake (ppm)	Zn uptake (ppm)
1%	2:1	43.52	111.8	2.57	1.11	48.44	124.1
	25:1	45.93	469.0	10.21	1.04	47.92	488.4
	100:1	45.28	1472.4	32.71	1.19	54.03	1756.3
	150:1	45.57	2237.6	49.18	0.93	42.28	2077.3
	200:1	41.39	2520.4	60.93	1.24	51.55	3135.5
Mean		**44.34**	**1362.2**	**31.12**	**1.10**	**48.84**	**1516.3**
3%	2:1	36.55	147.0	4.03	0.27	9.86	39.7
	25:1	31.58	493.7	14.28	0.37	11.52	181.4
	100:1	34.91	1199.6	34.41	0.62	21.53	738.8
	150:1	45.51	2004.7	44.04	0.93	42.14	1856.3
	200:1	41.37	3292.3	79.56	0.48	20.09	1598.7
Mean		**38.65**	**1427.5**	**35.26**	**0.53**	**21.03**	**883.0**
F test (OM)		**	*	**	**	**	**
L.S.D 0.05 (Zn:Cd ratio)		**3.26**	**99.1**	**2.55**	**0.08**	**5.11**	**166.0**
L.S.D 0.05 (OM× Zn:Cd ratio)		**4.63**	**140.7**	**3.61**	**0.12**	**7.25**	**235.5**

Although in the presence of 1% OM there were no significant changes in Cd content with increasing Zn application, a slight increase was detected up to a ratio of 150:1, then the concentration decreased with 200:1 Zn:Cd ratio. On the other hand, the application of 3% OM along with Zn applications had the same effects on Cd content that were found in the previous experiments. Up to a ratio of 25:1 Zn:Cd caused a significant reduction in Cd concentration , this reduction started to gradually and significantly recover with the gradual increase of Zn up to 150:1. Where as the ratio 200:1 reduced Cd content (compared with the previous application) due to the toxic effect of Zn. Organic matter in soil binds to Cd making plant uptake difficult (Eriksson, 1990), so increasing the organic matter in soil should reduce plant available Cd. Dry Matter yield was improved with the application of farmyard manure by raducing the Cd supply from the soil leading to decrease Cd concentration and increase Zn concentration in plants (Talatam and Parida, 2009).

Normally, Zn content and Zn:Cd ratio were gradually and significantly increased with increasing Zn application with both OM levels.

Conclusions

The results from this experiment provide evidence that both lettuce and swiss chard have the ability to accumulate both cadmium and zinc in the leaf tissue. Increasing the Zn concentration appears to reduce the amount of Cd uptake by plants at Zn:Cd equal to or below 50:1. The salinity of the blend may affect both dry weight and Cd uptake of the growing plants, thus leaching such soil may be effective befor planting. In addition, accumulation by lettuce and swiss chard suggest that phytoextraction, when using different plant species, may be a valuable tool for PSC Phosphate Aurora facility in Aurora, North Carolina.

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نمو نباتات الخس و السلق و محتواهما من الكادميوم تحت تأثير اضافة الزنك و صخر الفوسفات و الماده العضويه

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الهدف من هذه الدراسه هو محاولة خفض محتوى النباتات من عنصر الكادميوم باستخدام الزنك و صخر الفوسفات و الماده العضويه. تم اجراء بعض تجارب الاصص فى الصوبه الخاصه بجامعة نورث كارولينا بالولايات المتحده الامريكيه.

تم استخدام مخلفات صناعة الفوسفات التى تحتوى على نسب من الزنك: الكادميوم تعادل 2:1 و تم زراعه الخس فى الموسم الاول مع معاملات تم فيها تعديل نسبة الزنك : الكادميوم الى 1:2، 1:5 ، 1: 15 ، 1:20 ، 1:25 ، 1:50 ، 1:75 ، 1:100 ، 1: 150 ، 1:200 كما تم عمل معاملات اخرى باضافة صخر الفوسفات للتربه بنسب 0,5 – 1 – 2,5 – 5 ٪ . و تم دراسة التأثير المتبقى لهذه المعاملات بزراعة نباتات السلق فى نفس التربه المعامله سابقا . تم اختيار خمس معاملات من الزنك (1:2 ، 1:25 ، 1:100 ، 1:150 ، 1:200) مع مستويات من الماده العضويه (1٪ و 3٪ من الكمبوست) لمعرفة تأثير الماده العضويه مع الزنك على امتصاص الكادميوم.

اظهرت النتائج انخفاض محتوى الكادميوم فى نباتات الخس معنويا بالتدريج من 69,95 جزء فى المليون فى التربه الغير معامله (نسبة زنك : كادميوم 1:2) الى 29,64 جزء فى المليون مع نسبة زنك : كادميوم 1:50 ومن 40,41 جزء فى المليون الى 32,11 جزء فى المليون فى نبات السلق النامى فى تربه بها 1:25 زنك : كادميوم. ادت اضافة 5٪ من صخر الفوسفات للتربه الى انخفاض امتصاص الكادميوم من 19,00 جزء فى المليون فى التربه الاصليه الى 12,59 جزء فى المليون و من 35,17 جزء فى المليون الى 28,19 جزء فى المليون فى كل من الخس و السلق على التوالى. بصفه عامه ادت اضافة 3٪ ماده عضويه الى انخفاض امتصاص الكادميوم فى كلا النباتين.