CADMIUM AVAILABILITY AND ROLE OF ZINC IN CADMIUM TOLERANCE OF RICE (*ORYZA SATIVA*)

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Introduction

Chronic kidney disease has become a major health problem in Sri Lanka in last 10-15 years. Chronic kidney disease (CKD) also known as chronic renal failure is a progressive loss of renal function over a period of years. In many CKD patients, previous renal disease or other underlying diseases are already known. The other patients present with CKD of unknown cause. In these patients, a cause is occasionally identified retrospectively. CKD of uncertain aetiology (CKDue) is common among people who involve in Agriculture as their occupation. Geographically it is distributed in North Central region mainly in Medawachchiya, Girandurukotte, Kabathigollewa, Padaviya, Medirigiriya, Dehiattakandiya and Nikawewa regions (Bandara *et al.*, 2007)

Several studies have been performed to find the aetiology and many hypotheses are put forward. Excessive quantities of naturally found fluoride in the ground water which can harm the kidneys, excessive use of fertilizers, insecticides and weedicides, the use of aluminium utensils made out of low quality cheap aluminium to store water and to prepare food, entry of toxic element such as Arsenic, Lead, Cadmium via food chain, excessive use of poor quality illegal liquor, mycotoxins, use of herbal/ Ayurvedic medicines, smoking, history of snake bites have been the possible reasons. Bandara *et al.* (2007) reported that the elevated dietary cadmium levels in rice and fresh water fish in farm lands under cascade irrigation systems in North Central Province in Sri Lanka are the main cause of chronic renal failure prevalent in the area. It is also confirmed by the latest article (2011) written by Shanthi Mendis, senior advisor in WHO. This article however mentioned that a exposure to a combination of factors that are toxic to the kidney (rather than one single factor) seems to cause this disease. Toxic factors identified up to now include nephrotoxic agrochemicals, arsenic and Cadmium.

In Japan, "Itai Itai " disease due to cadmium toxicity was a problem caused by the addition of cadmium to water by an industrial accident, resulting high level of cadmium in irrigation water of rice crops. Rice grain absorbed cadmium which resulted in poisoning consumers resulted in kidney failure and death. The maximum permissible level of Cd recommended by CODEX (2009) for polished rice grain is 0.4 mg/kg.

Cd and Zn are elements having similar geochemical and environmental properties. Their chemical similarity can lead to interaction between Cd and Zn during plant uptake and accumulation in edible plant parts. Most of the experiments are dealing with the interaction between Cd and Zn in plants. But the effect of Zn on Cd uptake and accumulation in plants are not consistent. This shows either synergistic (Pitrowska *et al.*, 1992; Smilde *et al.*,1992; Salt *et al.*, 1995) or antagonistic pattern (Li *et al.*, 1990; Long *et al.*, 2003). The present study was aimed at determine the level of Cd in paddy land soils of the Padaviya district and to study the effect of Zn on Cd uptake and accumulation by selected rice varieties grown in Sri Lanka.

Methodology

The experiment 01 was conducted to determine level of Cd content in paddy land soil. Fourteen villages were basically selected for the soil sampling in Padaviya district. From each village two households were selected based on the number of patients recorded from each house. Then soil samples from each house were collected from their own paddy fields which were frequently used for the paddy farming. Samples were collected from five points of the selected plots, two on both diagonals, one meter from the corners, and one on the intersection points of the diagonals. Samples were collected at a 0-30 cm depth using a soil auger from the selected locations of all the plots. Each sample was packed in polypropylene bags, labeled. Then each sample taken to the laboratory for chemical analysis. Experiment 02 was carried out as a pot experiment to investigate the effect of Zinc on Cadmium uptake and translocation. Six kilogram of soil were used in this pot experiment and contaminated with 25mg/kg of Cd. Cadmium - Zinc interaction were determined at 25mg/kg of Cd plus 0, 25, 50 mg/kg of Zn addition as a Zinc sulfate with two rice varieties namely, Bg300 and *Kaluheenati* from each plant group. At the end of the ripening stage plants were uprooted and Cd content in grain, shoot and roots were measured. The sample Cd concentration level was recorded using a GF-AAS; Model: GBC GF3000.

Experimental Results & Discussion

The level of Cd in paddy land soils of the Padaviya district

The highest soil Cd level was detected in Padaviparakramapura area was 7.856 ppb (Table 1) level of Cd. The lowest Cd level was recorded in Rathmale area. However when calculating the average soil Cd level in Padaviya area was 4.897 ppb and when it is converted to the dry soil basis; it contains 0.408 mg/kg of Cd.

Table 1: Average Cd level in paddy soil sample in Padaviya district

Village	*Avg. Cd level in ppb*	
	Sample 01	***Sample 02***
Nikawewa	5.463	4.356
Kalyanapura	3.47	5.243
Ahatugaswewa	4.446	4.993
Kiriibbanwewa	5.28	4.86
Sudarshanagama	5.97	6.186
Maithreepura	7.173	5.713
Mahagalkulama	7.04	3.936
Ruwanpura	5.066	4.6
Mahasenpura	3.496	3.293
Koanketiyawa	2.97	3.656
Aluthhalmillewa	3.72	3.046
Rathmale	3.533	2.8
Buddangala	5.896	5.626
Padaviparakramapura	7.856	6.51

The maximum acceptable upper limit (3 mg/kg) imposed by the European community set standards in 1986 (Mc Grath *et al.*1994). When considering the experimental value it does not exceed the maximum acceptable upper limit at all. With these values it is difficult to conclude that the soil samples were highly polluted with the heavy metal Cd.

Effect of Zn treatment on plant uptake and accumulation

Cadmium concentration in grains of rice grown under constant Cd level (25 mg/kg) and varied Zn levels are shown in table 2. The study exposed that Variety *Kaluheenati* significantly ($p<0.05$) increased their grain Cd levels with increasing soil Zn level. Similarly Bg 300 increased their grain Cd level when soil Zn level was changed from 0 to 25 mg/kg; however, that was not significant but the increasing soil Zn level from 25 to 50 mg/kg caused the significant ($p< 0.05$) increased of grain Cd concentration in Bg 300.

Table 2: Cadmium concentration in grains of rice grown under constant Cd level (25 mg/kg) and varied Zn levels

Variety	*Treatment Soil Zn level*	*Cd Concentrations (mg/kg)*		
		Grain	*Shoot*	*Root*
Bg 300	Control (0 mg/kg)	0.4139± 0.0808 [a]	1.1650 ± 0.1443 [a]	13.7128 ± 1.762 [a]
	25 mg/kg	0.7750± 0.2677 [a]	3.4397 ± 0.1222 [b]	36.6451 ± 7.119 [b]
	50 mg/kg	1.9659± 0.1277 [b]	5.4676 ± 0.6739 [c]	88.5348 ± 6.549 [c]
Kaluheenati	Control (0 mg/kg)	0.7259± 0.1436 [a]	2.2475 ± 0.1657 [a]	23.498 ± 2.379 [a]
	25 mg/kg	2.0977± 0.1744 [b]	2.9393 ± 0.6399 [a]	56.712 ± 10.937 [b]
	50 mg/kg	2.6252± 0.0757 [c]	5.1604 ± 0.2220 [b]	31.259 ± 7.244 [a]

Values are mean ± S.D. (n=3); Interaction between rice variety and Cd level is significantly different;
Means in rows followed by the different simple letters are significantly different at $p=0.05$ (Duncan test).

In both tested rice varieties the mean shoot Cd content was increased significantly ($P<0.05$) with increasing Zn level in soil. It was highly significant in Bg 300; however in *Kaluheenati* the Cd concentration in shoots was not significant ($p<0.05$) at the level of 0 to 25 mg/kg but it was significant when increasing Zn level from 25 to 50 mg/kg. Root Cd concentration in variety Bg 300 was significantly increased with the increasing Zn level in soil. But different results were showed in variety *Kaluheenati* at the tested Zn levels. Root Cd content in *Kaluheenati* variety was increased with the increasing soil Zn level from 0 to 25 mg/kg. However it was drastically reduced with increasing soil Zn level up to 50 mg/kg. It is noted that lower amount of Cd in their roots at 50 mg/kg than the 25 mg/kg of Zn level in soil. Thus Zn had a synergistic effect observed in grains, shoot and roots of Bg300 and grains shoot of *Kaluheenati* except the roots. These results agreed with the previous reports of Hinsely *et al.*, who has reported that repeated sludge applications did result in additional increase of both Cd and Zn contents in corn leaves and grain in calcareous soils. Further our findings are in broad agreement with those of the following reports. Smilde *et al.* 1992 concluded that Zn and Cd were synergistic to some extent, plant Zn uptake increasing with applied Cd on the basis of interaction experiment carried out in loam soil in pots. Also Moraghan, 1993 reported that the Cd and Zn effects were synergistic to each other in the presence of added Cd. Further he reported Cd accumulation in flax seed was reduced by added Zn in the absence of added Cd. The present results also suggest that in rice pots highly contaminated with Cd and Zn, soil Zn should not be expected to decrease Cd significantly in crop parts although there is a strong antagonistic Zn effect on Cd accumulation in plant tissues.

Conclusion

Average soil Cd level in Padaviya area was 4.897 ppb / 0.408 mg/kg of Cd. But the experimental value is not exceeds the maximum acceptable upper limit at all. Also the concentration of Cd in grains, shoot and roots of rice were increased with increasing Zn supply levels. Therefore it showed synergistic effect. It can be concluded that these results might depend on plant species and external Cd and Zn concentration levels.

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