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Effect of Organic Fertilizer on Cadmium Uptake by Rice Grown in Contaminated Soil

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Abstract. Organic fertilizer effects on cadmium uptake by rice grown in contaminated soil was studied and tracked throughout the experiment which was conducted in a plant nursery house. Five samples of soil in planting containers were prepared by filling with soil using uncontaminated and organic fertilizer free, contaminated and organic fertilizer free, contaminated and organic fertilized at 500 kg/rai (6.25 rai = 1 hectare) , contaminated and organic fertilized at 1000 kg/rai and contaminated and organic fertilized at 2000 kg/rai. Then 4 varieties of Thai rice as follows: Khao Dawk Mali 105 (KDML105), RD6, Phitsanulok3 and Niaw San-Pa-Tong were cropped in each container. Afterwards, samplings of the soil and successfully grown rice were taken every 30, 60, 90 and 120 days. These consisted of above soil surface growth; below soil surface growth, husk and grain these were to determine the amount of Cadmium uptake in each part. The experimental results show that Niaw San-Pa-Tong cropped in contaminated soil with organic fertilizer at 2000 kg/rai, after 120days displayed accumulated cadmium uptake in above soil surface was lowest at 4.1 mg/kg. At the same time interval, Phitsanulok3 grown in contaminated soil and fertilized at 1000 kg/rai, revealed cadmium uptake in below soil surface was lowest at 9.19 mg/kg. Cadmium uptake by Phitsanulok3 grain reached to its lowest at 0.06 mg/kg in soil contaminated and fertilized at 2000 kg/rai. These results suggest that, regarding accumulative cadmium uptake, a concentration of organic fertilizer in the level ranging between 1000-2000 kg/rai will be most successful in the future.

Keywords: Organic Fertilizer, Cadmium, Uptake, Rice, Soil

1. Introduction

Nowadays the country's environmental problems induced by every single source have turned into a crisis that will have a negative effect on human health and all living creatures. This is especially shown in the problems occurred by heavy metal hazardous waste contamination entering into soil and water resources. Primarily this comes from activities such as, mining and agricultural practices that disturb the soil. In these practices heavy metals are drained into the water holding soil layers both on the surface and under ground and are eventually retained in the soil.

A report of the International Water Management Institute showed cadmium contamination both in soil and agricultural products in the North of Thailand [1]. For this reason, a promotional campaign was instituted for the rice farmers to cultivate sugarcane in substitution of rice to be used in ethanol production not food use. Beyond that it was thought cane would be helpful in cadmium uptake from soil. Some rice farmers were reluctant to follow this transition and insisted on growing their rice for survival. Others whose land plots were not fit for sugar cane growing continued their rice crops. Presumably the cadmium contamination permeated their crops. This study evaluated the cadmium uptake by rice grown in greenhouse conditions using four varieties of rice; Khao Dawk Mali 105 (KDML105), RD6, Phitsanulok3 and Niaw San-Pa-Tong and soil

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taken from the actual area of contamination. By extension, it can be implied that the statistical data of the representative samples of cadmium uptake is representative of the actual land and crops. Although cow manure was applied as the organic fertilizer material in this study it could be anticipated that commercial organic fertilizer would convert cadmium in a similar fashion. Hence, this study produced a better understanding of how organic fertilizer usage related to cadmium retains ability of soil and rice roots. The experimental study results should be helpful in determining appropriate amounts of organic fertilizer rice farmers should use to return farm land to productive food crop use.

2. Materials and Methods

2.1. Cadmium uptake experiment

1) Soil preparation: We surveyed soil from the area that was contaminated with cadmium using guidance data from the Geographic Information System (GIS), National Research Center for Environmental and Hazardous Waste Management, Chulalongkorn University (2005) that identifies the area locations and the degree of cadmium contamination. We also randomly collected some soil for further accumulative cadmium uptake analysis. Once the area was determined, we collected soil samples at 0-30 cm. depth which were randomly brought to laboratory for analyzing. Soil samples were analyzed for properties (soil properties) with the following parameters: soil texture, pH, cation exchange capacity (CEC), electrical conductivity (EC), and organic matter in soil (OM) i.e. Nitrogen (N), Phosphorous (P), Potassium (K), and the total amount of cadmium (Total Cd).

2) Preparation of planting container: used plastic buckets with 30 cm. diameter top, 20 cm diameter bin bottom and 30 cm. heights as the planting container. Soil contaminated with cadmium was weighed out to 10 kg dry weight and then placed in the experimental buckets for a total of 16 units.

3) Preparation of experimental plant: selection of the following rice varieties, Khao Dawk Mali 105 (KDML105), RD6, Phitsanulok3 and Niaw San-Pa-Tong; from the Department of Rice, Ministry of Agriculture and Co-operation. The criterion of grain selection was those of similar size and weight as well as the percentage of germination should be above 90.

4) Preparation of organic fertilizer: cow manure was brought in for experimental use from the area uncontaminated by cadmium and analyzed to be confirming it was cadmium free. It was desiccated until dried It was applied at ratios of 0, 500, 1000 and 2000 kg/rai.

5) Growth and care: Each container was planted with 3 grain seeds the sapling received regular watering and flood level control within limit throughout the trial duration. As soon as the rice reached its grain optimum it was left to dry and then we waited until the grain was ready for harvesting. Throughout the experiment, neither chemical fertilizer nor any other functional chemicals were added in.

6) The sampled soil and rice at intervals of 30, 60, 90 and 120 days which corresponds to stage of sprout, shoot, granulation and harvest respectively Later we determined the cadmium uptake from the soil. The parts of the rice collected were washed with clean water then sorted into two groups follows: parts above soil surface (rice stem) and those underneath soil surface rice root) and next, treated in the hot air oven set at 105 °C for between 24-48 hours until reaching a consistent weight. The dried parts were into fine powder and analyzed for total Cadmium. At the final time interval of 120 days, the sampling consisted of grain seed and husk samples which were stepped on and analyzed for cadmium uptake as well.

7) The sampling of water: water samples that had been trapped in the bucket containers were collected 4 times in every aspect of experiment at intervals of 30, 60, 90 and 120 days. The samples collected were kept in 200 ml. glass bottles to which was added 2-3 drops of 65% Nitric Acid before refrigeration. Then they were analyzed for total Cd.

2.2. Analytical methods

The analysis of cadmium in soil and 4 different parts of rice: above soil surface, beneath soil surface, grain and husk was conducted using USEPA method 3052 [2]. The analysis of cadmium determination in water was performed using USEPA method 3051A [3] by acid digestion technique with a microwave digestion and followed by measurement of total cadmium with Atomic Absorption Spectrometer; AAS.

3. Statistical Analyses

The statistical data variance of accumulative cadmium uptake from the soil as well as total cadmium uptake by rice was analyzed by Analysis of Variance (ANOVA) statistical models, at the 95% confidence level. The data variance was compared with those of means using Duncan's New Multiple Range Test (DMRT) and afterwards we utilized SPSS Statistical Package for the Social Science to analyze data into operational solutions.

4. Results and Discussion

4.1. Soil properties

Soil applied in this experiment was of the texture class clay loam, other properties are shown in below in Table 1. We found that the experimental soil demonstrated cadmium accumulate at 68.9 mg/kg which exceeders the standard for safe soil for food crop cultivation.

4.2. Soil pH

The analysis results show the following concentration aspects of organic fertilizer application; 500, 1000 and 2000 kg/rai, pH in soil cultivated with Khao Dawk Mali 105 resulted in three ranges from 7.80 to 7.86, 7.75 to 8.01 and 7.67 to 7.81; RD6 ranged from 7.81 to 7.87, 7.81 to 7.96 and 7.88 to 8.01; Phitsanulok3 ranged from 7.40 to 7.77, 7.82 to 7.94 and 7.84 to 7.94, and Niaw San-Pa-Tong ranged from 7.74 to 8.02; 7.27 to 7.83 and 7.83 to 7.96. The pH changes were minor since the organic fertilizers applied interacted with the cadmium and formed metal complex compounds that made pH in soil change gradually [4].

4.3. Cadmium accumulation in water and soil

1) Accumulation of cadmium in water: Cadmium in the water that was trapped in the experimental containers where Khao Dawk Mali 105, RD6, Phitsanulok3 and Niaw San-Pa-Tong were cropped is displayed in Table 2. The detected no significant amount of cadmium in water when compared with that in soil. This shows that the loss of cadmium into water was minimal.

Table 1 Fundamental properties of the experimental soil

Parameters	Properties
Sandy Clay (%)	33.2
Silty Clay (%)	32.0
Clay (%)	34.8
Texture Class	Clay Loam
pH	7.4
CEC (c $mol_{(+)}kg^{-1}$)	15.5
EC (ds m^{-1})	0.125
Organic Matters (%)	2.18
Nitrogen (%)	0.109
Phosphorous (ppm)	21
Potassium (ppm)	150
Cadmium (mg kg^{-1})	68.9

Table 2 Cadmium amount in water

Rice varieties	Organic fertilizer amount applied	Accumulative Cd amount at time intervals (mg/L)			
		30 days	60 days	90 days	120 days
Khao Dawk Mali 105	0	0.072	0.123	0.056	0.379
	500	0.062	0.082	0.123	0.354
	1000	0.085	0.092	0.066	0.261
	2000	0.077	0.026	0.082	0.397
RD6	0	0.058	0.054	0.113	0.392
	500	0.02	0.089	0.122	0.131
	1000	0.071	0.035	0.131	0.283
	2000	0.082	0.057	0.036	0.275
Phitsanulok3	0	0.087	0.012	0.114	0.254

	500	0.057	0.074	0.28	0.198
	1000	0.064	0.103	0.17	0.216
	2000	0.097	0.053	0.11	0.17
Niaw San-Pa-Tong	0	0.041	0.109	0.174	0.105
	500	0.105	0.077	0.147	0.301
	1000	0.106	0.053	0.142	0.198
	2000	0.111	0.116	0.122	0.368

2) Accumulation of cadmium uptake from soil: Accumulative cadmium uptake from the soil with organic fertilizer concentrated at 0, 500, 1000 and 2000 kg/rai, at sampling time 120 days, by Khao Dawk Mali 105 were 55.06, 67.18, 76.73 and 68.62 mg/kg, respectively; RD6 were 39.20, 56.96, 85.49 and 75.54 mg/kg, respectively; Phitsanulok3 were 36.42, 67.17, 71.18 and 70.21 mg/kg, respectively and Niaw San-Pa-Tong were 40.76, 67.22, 77.18 and 77.52 mg/kg respectively.

From the analysis, the accumulative cadmium uptake from soil by the varieties of rice cropped in the greenhouse (Fig. 1) show that cadmium uptake from soil without organic fertilizer was less than that of with organic fertilizer in every single trial as follows; all studied concentration, all intervals and all experimental rice varieties cropped. Thus, this suggests that cadmium uptake from soil with organic fertilizer would be lower due to the fact that the application of organic fertilizer would enhance heavy metals retention in soil since organic matter possess many negative ions that could attract positive ions 2-30 times better than other colloids. For this reason the application of organic fertilizer into soil will help prevent heavy metal uptake [5].

4.4. Cadmium uptake by rice

From the analysis, the accumulation of cadmium up taken by above soil surface rice parts (stems and leaves), cropped in soil with organic fertilizer at concentration 0, 500, 1000 and 2000 kg/rai, at 120-day sampling, of which Khao Dawk Mali 105 were 8.00, 7.17, 5.84 and 5.61 mg/kg, respectively; RD6 were 8.67, 8.09, 5.04 and 4.67 mg/kg, respectively; Phitsanulok3 were 4.84, 7.24, 4.57 and 8.21 mg/kg, respectively and Niaw San-Pa-Tong were 6.29, 5.42, 8.27 and 4.10 mg/kg, respectively. From the analysis, the accumulation of cadmium up taken by below soil surface rice parts (rice roots), cropped in soil with the same organic fertilizer concentrations, at 120-day sampling, of which Khao Dawk Mali 105 were 23.05, 28.98, 21.63 and 19.43 mg/kg, respectively; RD6 were 20.52, 22.61, 11.72 and 13.08 mg/kg, respectively; Phitsanulok3 were 29.63, 20.06, 9.12 and 9.42 mg/kg, respectively and Niaw San-Pa-Tong were 26.76, 17.65, 18.63 and 10.73 mg/kg, respectively.

Figure 2 and 3 demonstrate that the accumulated cadmium uptakes by both above and underneath soil surface rice parts tended to decrease over time. We also found that in all experimental rice varieties, the cadmium uptakes, by both above and underneath soil surface parts of rice cropped in soil with any studied concentration aspects of organic fertilizer, were lower than that without organic fertilizer. This was in conformance with cadmium uptake from soil using organic compounds mixed by sediment and rice straw that resulted in its slow rate [6]. Also for all varieties of the experimental rice, Cadmium up taken by their roots was higher than by their stems. This was as well consistent with the accumulated cadmium uptakes by three other plants; rice, soybean and maize, that were grown in soil contaminated by cadmium [7]. From the analysis of accumulated cadmium uptake by rice husk, we determined Khao Dawk Mali 105 and RD6 showed lowest at 8.16 and 9.16 mg/kg, respectively, under the soil with organic fertilizer applied at 2000 kg/rai. Phitsanulok3 cadmium uptake came in lowest at 9.38 mg/kg under the soil with organic fertilizer concentrated at 1000 kg/rai. And for the Niaw San-Pa-Tong, its cadmium uptake reached its lowest at 4.78 mg/kg under the soil with organic fertilizer concentrated at 500 kg/rai. For grain analysis, the cadmium uptakes, by all of the rice studied; Khao Dawk Mali 105, RD6, Phitsanulok3 and Niaw San-Pa-Tong, consistently dropped to their lowest under the soil with organic fertilizer concentrated at 2000 kg/rai, to 0.11, 0.09, 0.06 and 0.07 mg/kg, respectively.

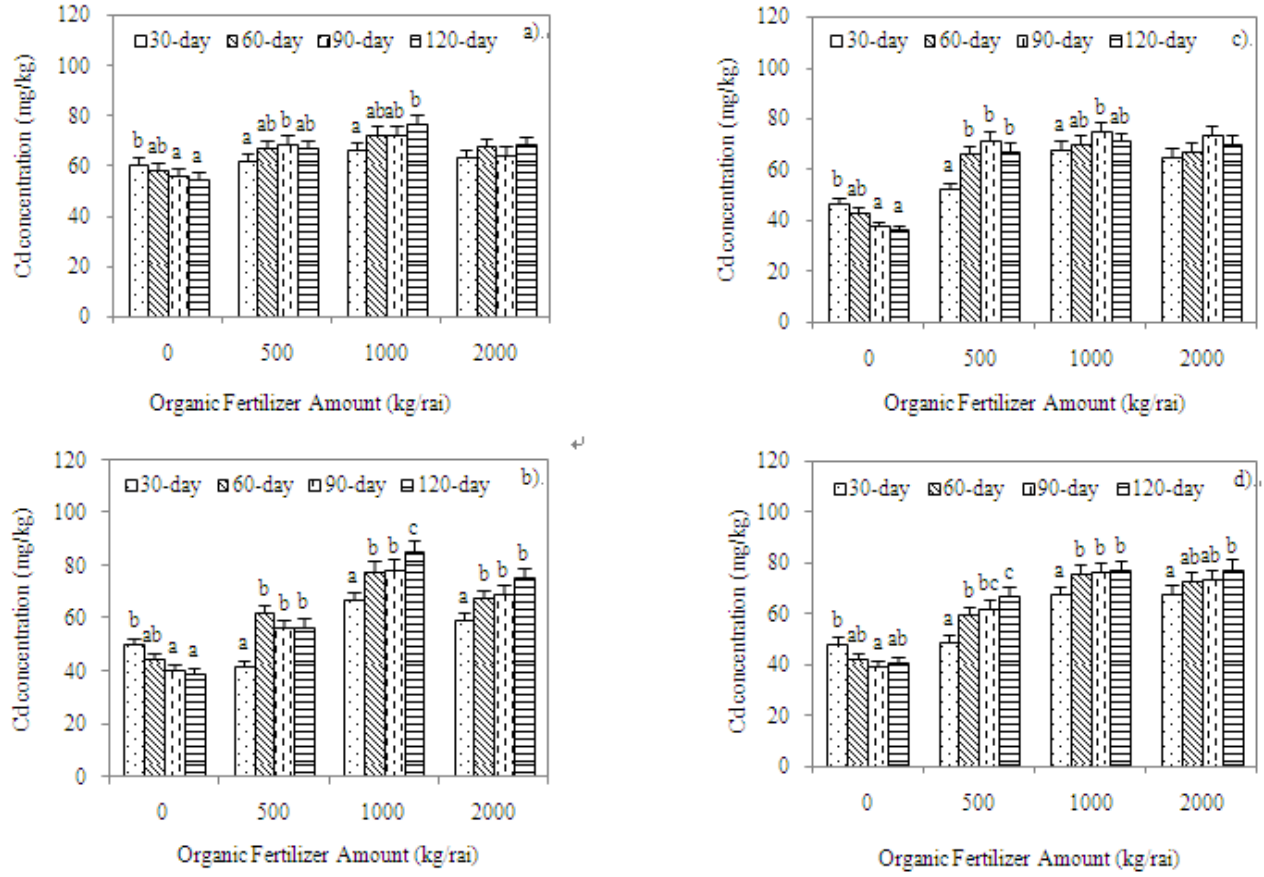

Fig. 1 : Accumulation of cadmium uptake from soil by each rice variety cropped in nursery.

a) Khao Dawk Mali 105 b) RD6 c) Phitsanulok3 and d) Niaw San-Pa-Tong

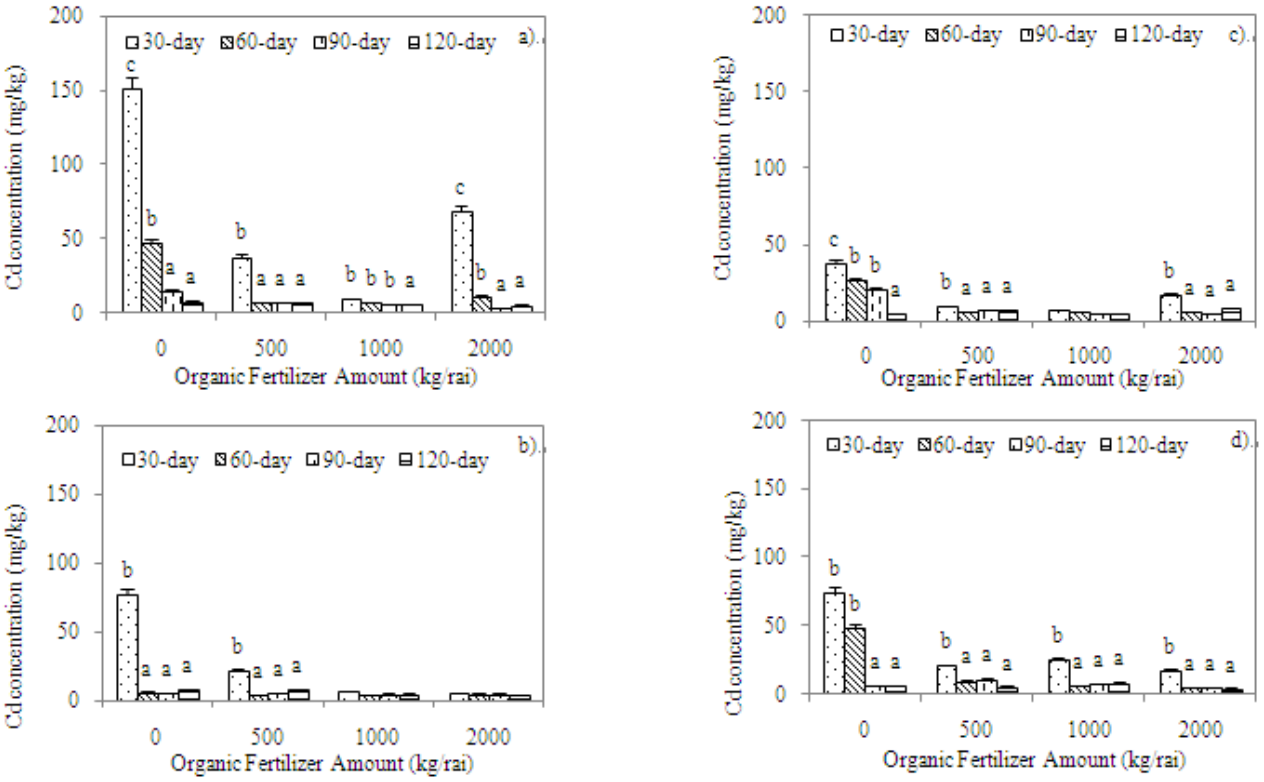

Fig. 2 : Accumulation of cadmium uptake by above soil surface rice parts (stems and leaves).

a) Khao Dawk Mali 105 b) RD6 c) Phitsanulok3 and d) Niaw San-Pa-Tong

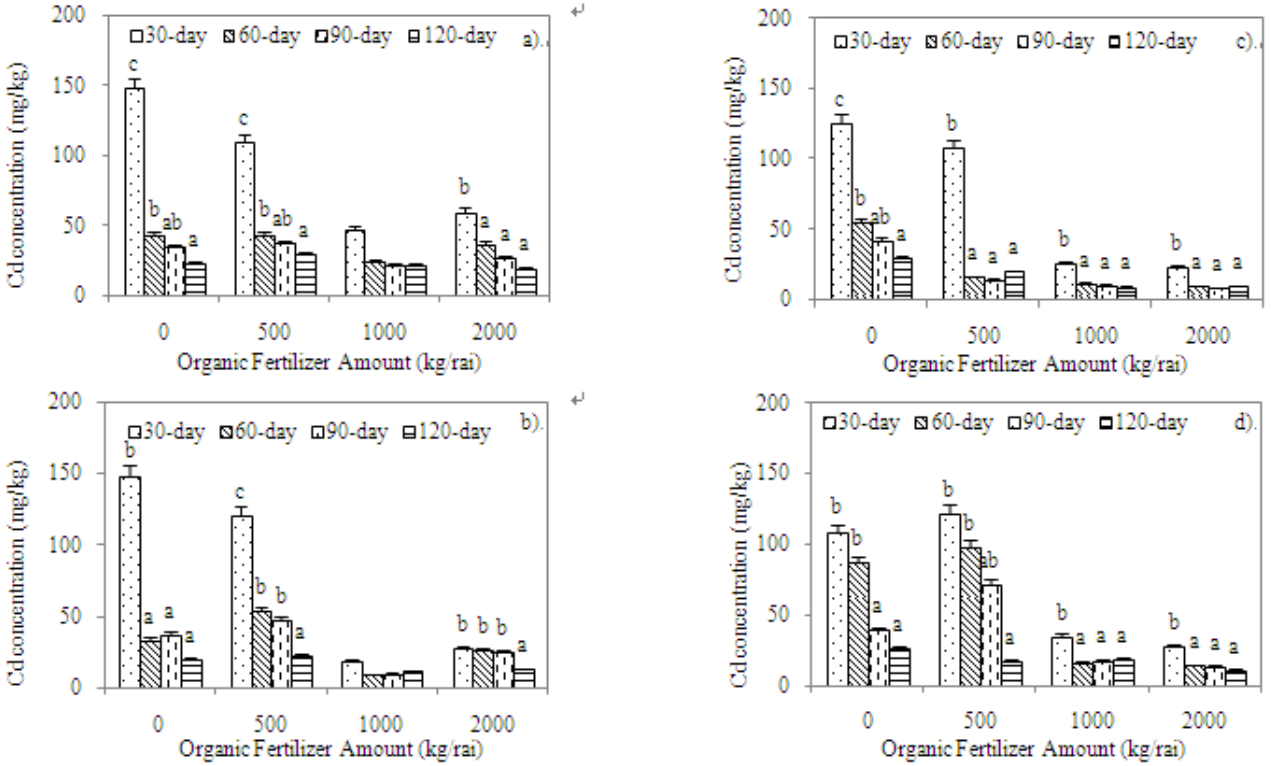

Fig. 3 : Accumulation of cadmium uptake by under soil surface rice parts (rice roots).

a) Khao Dawk Mali 105 b) RD6 c) Phitsanulok3 and d) Niaw San-Pa-Tong

Figure 4 shows for all varieties of rice studied their cadmium uptake by the husk and grain of rice cropped in soil without organic fertilizer, were lower than that with organic fertilizer at all studied concentrations. This suggests that husk and grain took up cadmium less from soil with organic fertilizer. This was consistent with the study of the effect of organic fertilizer and potassium hydroxide addition to soil on cadmium adsorption [8].

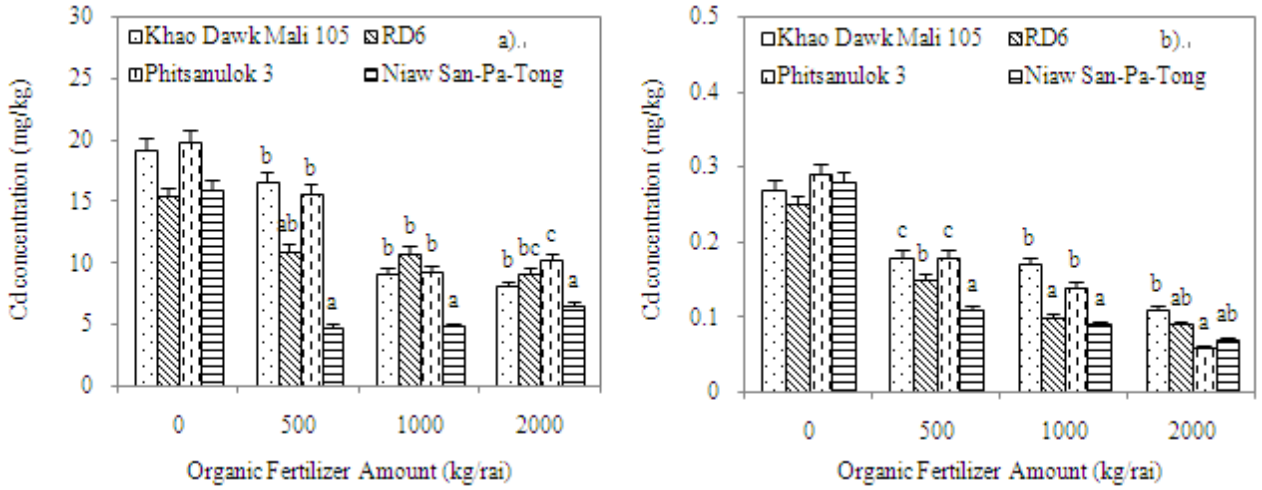

Fig. 4 : Accumulation of cadmium uptake.

a) Husk and b) Grain

5. Conclusions

The analyzed results show the organic fertilizer in soil correlated to higher accumulative cadmium uptakes in every interval sampling and all varieties of rice, or to say, and all studied aspects. Thus we conclude that organic fertilizer can secure cadmium within soil and 1000 kg/rai concentration would trigger the optimum results. Specifically, variety by variety, cadmium uptakes by common rice by parts both above and underneath soil surface reached its lowest under condition of 1000 kg/rai organic fertilized soil at 120-day sampling. The cadmium uptakes by Phitsanulok3 were less than that by Khao Dawk Mali 105. While, the cadmium up taken by Niaw San-Pa-Tong reached to its lowest under the condition of 2000 kg/rai, organic fertilized soil at 120 day sampling. The cadmium uptakes by RD6 were lower than that by Niaw San-Pa-Tong, and dropped to its lowest under the condition of 2000 kg/rai organic fertilized soil. For Cd uptake by grain Phitsanulok3 absorbed the least. In this experiment using the condition of organic fertilization, the cadmium uptakes from grain did not exceed the standard set by the EU of not more than 0.2 mg/kg [9].

6. Acknowledgements

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