Soil management for reduce Cd concentration in rice grains

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Abstract
Cadmium contaminated soils have a health and socio-economic impact on people who live in that area. Food safety and quality becomes a social concerning issue. To obtain the information on cadmium accumulated in rice grains, two rice varieties, Khao Dawk Mali 105 (Indica) and Khao' Yipun DOA1 (Japonica) were grown by farmer practice method, irrigation method and soil washing method. The results showed that irrigation and soil washing methods can reduce cadmium concentration in rice grains.

Key Words
Farmer practice, heavy metal, on-site wash, Oryza sativa, rice variety, submerge soil.

Introduction

Rice is the major crop in Thailand and most of Thai consume rice. Thailand produces about 30 million tons of rice per year to be consumed in the country and exported. (Office of Agricultural Economics 2008) Soil contaminated with cadmium causes uptake by plants. Rice contaminated with Cd may cause health and socio-economic impact on people. Guo *et al*. (2007) reported that japonica rice takes up and accumulates less Cd than indica rice. Irrigation is one of the soil management practices for reduce Cd concentration in rice grains (Simmons and Pongsakul 2003). Soil chemical washing was performed in a paddy field in Nagano Prefecture and considerably decreased the Cd concentrations in the rice straw and unpolished rice, from 0.91 and 0.31 mg/kg, respectively, in the unwashed soil to 0.18 and 0.053 mg/kg in the washed soil (Makino 2007).

Hypothesis
Hypothesis 1 In submerged paddy soil sulfate ions are reduced to sulfide resulting in the precipitation of the Cd and Zn minerals and rice will less uptake of Cd.

$$Cd^{2+} + S^{2-} \longrightarrow CdS \quad (1)$$

Hypothesis 2 After soil washing, Cd concentration in soil will decrease and rice will less uptake of Cd.

$$\text{Soil } Cd^{2+} + M^{2+} \longrightarrow \text{Soil } M^{2+} + Cd^{2+} \quad (2)$$

Objective
To study Cd uptake by Khao Dawk Mali 105 (Indica) and Khao' Yipun DOA1 (Japonica) by differnder various soil management.

Studied area
A paddy field in Mae Sot District, Tak Province at 47Q 0459779 and 1843130 was selected for the study.

Project duration
The project duration is one year from 2008 to 2009.

Methods

Treatment
Completely randomized design with 5 replications was used for the experiment.

Table 1. Soil management used in the experiment.

No.	Treatment
1. Control FP	Khao Dawk Mali 105 with farmer practice
2. FP2	Khao' Yipun DOA1 with farmer practice
3. RI	Irrigation method for Khao Dawk Mali 105
4. RI2	Irrigation method for Khao' Yipun DOA1
5. SW	Soil washing and follow by Khao Dawk Mali 105 plantation
6. SW2	Soil washing and follow by Yipun DOA1 plantation

Field preparation

FP: farmer practice by flooding the rice field during vegetative growth, reproductive growth and early stage of grain development.

RI: Rice field was flooded every growth stage.

SW: Soil washing with $FeCl_3$ solution.

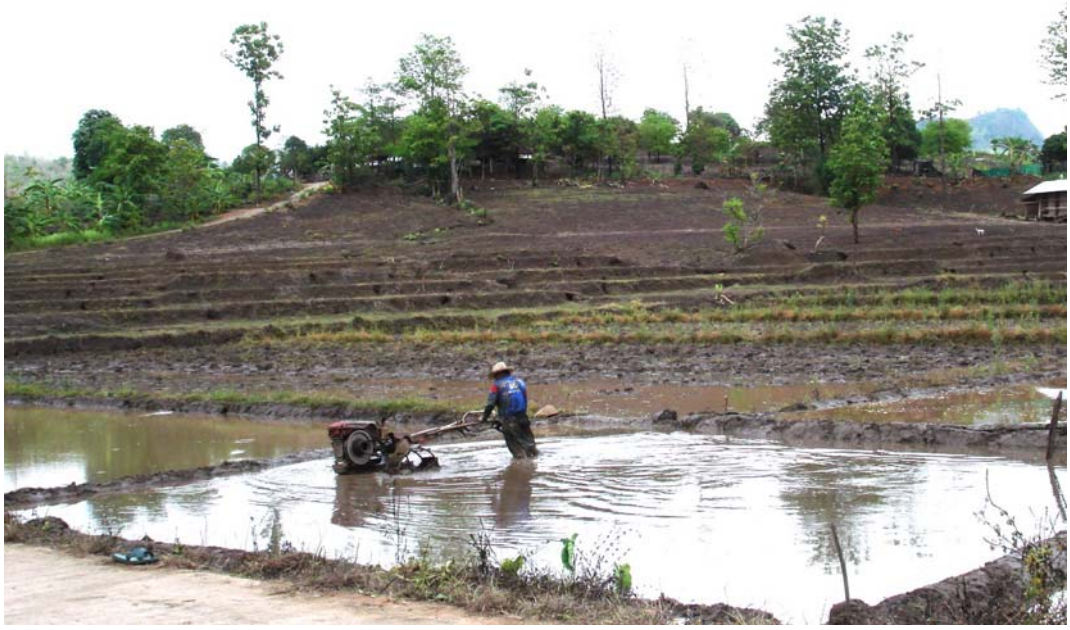

Figure 1. Field preparation for planting rice (29 April 2008).

Soil and rice grains sampling

Soil samples were collected from 15 random points (0-15 cm depth) in each treatment. The sample were air-dried and ground prior to analysis.

Rice grain samples were collected at physiological maturity from each treatment. All rice panicles were removed and placed in appropriately labeled paper bags. Grain samples were subsequently separated and oven dried at 65ºC for 72 hrs prior to de-hulling and grinding to a fine powder.

Analytical method

Total soil cadmium was determined in a 2 : 1 $HClO_4$: HNO_3 using an open tube digestion method and block digester. Plant samples were digested in 2 : 1 HNO_3 : $HClO_4$ using an open tube digestion technique (Zarcinas *et al*. 1983). Prior to digestion, plant samples were pre-digested overnight at room temperature to avoid excessive reaction on heating. Cadmium concentrations were determined using the Inductive Couple Plasma Emission Spectroscopy (ICP-OES) Perkin Elmer Optima 2100 DV.

Results

Soil characteristics

Soil properties of top soil are listed in Table 2. The soil texture was loam. The pH was 7.7 and electrical conductivity was low. Organic matter was very high. Cation exchange capacity was moderately high according to Soil Survey Division (1972). Plant nutrients were medium or low so fertilizer was applied. The concentration of As, Cu, Pb and Zn were at background level concentrations (Wild, 1993). Cadmium was high and indicated that soil was contaminated by Cd (Table 3).

Table 2. Soil characteristics.

Parameters	Unit	Topsoil (0-15 cm)
1. Texture		Loam
2. pH		7.7
3. OM	%	4.86
4. CEC	cmol/kg	15.8
5. EC	dS/m	0.14
6.Plant nutrient (Extractable)		
P	mg/kg	10.6
K	mg/kg	50.2
Ca	mg/kg	3640
Mg	mg/kg	325
Fe	mg/kg	71
Mn	mg/kg	19
Cu	mg/kg	2.56
Zn	mg/kg	17.6
Heavy metals (Total)		
As	mg/kg	12.6
Cd	mg/kg	5.94
Cu	mg/kg	11.3
Pb	mg/kg	16.0
Zn	mg/kg	202

Table 3. Average concentrations of heavy metals

Metal	Earth's crust (mg/kg)	Soils (mg/kg)	Rocks with highest concentration
As	1.5	0.1-50	shales and clays
Cd	0.1	0.01-2.4	shales and clays
Cu	50	2-250	basic
Pb	14	2-300	granite
Zn	75	10-300	shales and clays

Source: Adapted from Wild (1993)

Cd uptake by rice

Cadmium concentration in rice grains, shoot, root and husk for different treatments are presented in Table 4. The results showed that Cd concentration in Khao Dawk Mali 105 rice grains for the irrigation method and soil washing method was not significantly different. Significant differences were observed between Cd concentrations in rice grains for farmer practice method and the irrigation and soil washing methods. For Khao' Yipun DOA1, significant difference were observed between soil washing method and irrigation and farmer practice methods. Cadmium concentration in Khao Dawk Mali 105 in shoot and husk of soil washing method and irrigation and farmer practice method were significantly differences. Non-significant differences were obtained for irrigation method and soil washing method. Non-significant differences were also obtained for soil washing and irrigation methods and farmer practice method for Khao' Yipun DOA1. Rice roots accumulate high Cd concentration. Khao Dawk Mali 105, significant differences were observed between soil washing method and irrigation and farmer practice method. Significant differences were also observed between irrigation method and farmer practice method. According to result for Khao' Yipun DOA1, significant differences were observed between the irrigation method and soil washing method but non-significant differences were obtained between soil washing method and farmer practice method.

Table 4. Cadmium in rice grains, shoot, root and husk in different treatments.

Soil management	Rice varities	Cadmium concentration (mg/kg)			
		Rice grains	Shoot	Root	Husk
1. Farmer practice	Khao Dawk Mali 105	1.190 a	3.200 a	7.690 a	1.260 a
	Khao' Yipun DOA 1	0.050 d	0.280 b	6.350 b	0.120 b
2. Irrigation	Khao Dawk Mali 105	0.170 c	0.230 b	5.490 b	0.130 b
	Khao' Yipun DOA 1	0.096 d	0.430 b	3.262 c	0.100 b
3. Soil washing	Khao Dawk Mali 105	0.220 b	0.550 b	3.120 c	0.170 b
	Khao' Yipun DOA 1	0.150 c	0.540 b	5.660 b	0.110 b
F-test		**	**	**	**
CV (%)		11.9	30.6	17.7	27.0

Soil management by irrigation method and soil washing method can be used to reduce Cd concentration in rice grains. Cadmium was taken-up and accumulated in rice roots at higher concentration than in rice grain, shoot and husk.

Conclusion

Two rice types Khao Dawk Mali 105 and Khao' Yipun DOA1 was subjected to different soil management in a Cd contaminated soil context: (i) farmer practice, (ii) irrigation and (iii) soil washing method.
Soil management by irrigation and soil washing methods can reduce cadmium concentration in rice grains. Rice takes up and accumulates less Cd as can be explained by the following hypotheses.
Hypothesis 1 In submerged paddy soil sulfate ions are reduced to sulfide resulting in the precipitation of the Cd minerals and rice will uptake less Cd.
Hypothesis 2 After soil washing, Cd concentration in soil will decrease and rice will uptake less Cd.

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