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Cadmium Hoard and Production of Rice, Corn and Mungbean Swayed by Lime and Different Soils

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Abstract

The main goal of the research found out influences of limes and field soils on the Cd hoard of rice, corn and mungbean. There were two field experiments of rice, corn and mungbean with the soil inside and outside the dike in three communes (Long Binh, Khanh Binh and Khanh An) with two $CaCO_3$ rates (0.0, and 5.0 tons/ha). The experiment 1 and 2 included 18 and 6 treatments, respectively and four replications. Results presented that Cd concentration of rice seeds was the highest and lowest level of corn seeds. Plant seeds of Khanh An had The maximum Cd content and the minimum Cd level of plant seeds in Long Binh. The average Cd content of plant seeds of the soil inside the dyke was higher than 36.9% that of the soil outside the dike. The seed Cd content of 5.0 tons $CaCO_3$/ha was lower than 51.0 % that of non lime amendment. The lime amendment had the Cd hoard of stems and seeds of three plants which was lower than without lime application. Yields of the soil outside the dike of rice, corn and mungbean were higher than 20.5, 22.3 and 15.0%, those of the soil inside the dike, respectively. Yields of lime treatments of rice, corn and mungbean had higher than 17.9, 14.8 and 12.0%, those of without lime application, respectively. The lime amendment and the soil outside the dike was the perfect method to lessen the Cd store and increase the yield of crops.

Keywords: Cadmium, Corn, Inside the dike, Outside the dike, Mungbean, Rice

Introduction

The main foods, which have popularly used in the world are the rice, maize and mung beans. Three crops have been grown in many Southeast Asian countries and its production are the source of essential nutrients for humans [1]. The prior study was shown the Cd hoard of rice when planting on the Cd polluted soil [2]. Cadmium is a toxic element on the periodic table and presents in contaminated soil types a high risk to ecosystems and health's men through the agricultural produces. Plant uptake of Cd from contaminated soil is significant upon the chemical properties of soils and the biological characteristics of each plant [3]. Low quality Fertilizers are primary resources of the Cd contribution for soils and crops which have widely used in the agricultural cultivation. The high Cd level of the rice tends to increase in China [4].

Cultivation soils of An Phu district showed that high Cd contents of studied soil samples ranged from 37.1 to 380 ppb. The Cd accumulation of crops is mainly collected from the roots to the stems. Cadmium contents that is absorbed by plants may decrease as the soil pH increase [5, 2]. When lime application for the Cd-contaminated soil reduced the Cd absorption of plants by the average of 40 - 50% and maximum of 70% [6]. The Cd immobilization of the crop soils may cause by lime fixation, which is the efficient and cost-effective way [7]. The lime amendment reduced Cd levels of rice to 48.3% compared to no lime amendment sites [8]. The application of lime, organic manure combined with CaMgP fertilizers, which reduced the Cd accumulation of the rice from 37.5% to 52.8% compared to without lime treatment [9].

Lime applocation of acide soils reduced the solution Al^{3+} concentration of soil nearby zero. Lime, which could neutralize the available Al and Fe combined with anions on soil mineral surfaces [10]. Crop yields were not decreased after Al^{3+} concentrations of soil which saturated from 40 to 60%. Especially, lime application of acidic and Cd contaminated soils could reduce the mobility of Fe, Al and Cd, increase crop yield and lessen Cd accumulation of plants [11]. This research evaluated influences of liming, cadmum-contaminated soil and irrigation water on the Cd accumulation of rice, maize and mung beans under farm experiments.

Materials and methods

2.1 The field experiment design

Farm experiments were designed at three communes of An Phu district from february to july of 2021. Twenty four treatments were included eighteen treatments for experiment 1 and six treatments for experiment 2. The first experiment had three plant kinds (rice, corn and mungbean) x three communes (Long Binh, Khanh Binh and Khanh An) x two soil types (inside and outside the dike), the second experiment was involved in three plant types x two lime rates (without lime and five tons $CaCO_3$ per ha application) and four replications for two experiments (Table 2 & 3). The lime rates were applied the soil before 15 days tilling and the inorganic fertilizer following local tillers (Table 3). The irrigation water of study was without Cd contamination water (river water).

2.2 The physical-chemical properties of the initial experiment soils

Three communes, which are located in the small islet, the upstream of the Mekong Delta had the soil texture of sand silt loam; low pH (4.2-5.7), average total N (0.107 - 0.122), the total phosphorus of the soil was quite rich (>0.1%) and the available P was quite high (> 2.0 mg/kg). Phosphorus that has an important role in plant life tends to react with soil components to form insoluble compounds and slowly useful to plants. The exchangeble K was the medium level and ranged from 0.200 to 0.225 meq/100g. However, the Cd contents of of soil samples inside the dike, which were quite high and ranged from 382 to 511 mg/kg were higher two times than those of soil samples outside the dike (Table 1).

Table 1 Physical-chemical Properties of Soil in the initial experiment (n=30)

Commune	Soil	pH	Cd	Total N	Available P	Exchangeble K	soil texture (%)		
			(mg/kg)	(%)	(mg/kg)	meq/100g	Sand	Silt	clay
Long Binh	Inside the dike	4.5	440	0.118	2.201	0.223	20.0	60.9	19.1
	Outside the dike	5,5	170	0.112	2.031	0.203	20.5	60.7	18.8
Khanh Binh	Inside the dike	4.8	382	0.122	2.931	0.225	21.5	60.0	18.5
	Outside the dike	5.7	145	0.107	2.331	0.205	22.5	61.7	15.8
Khanh An	Inside the dike	4.2	511	0.119	2.431	0.215	20.5	62.0	17.5
	Outside the dike	5.2	212	0.108	2.001	0.200	20.1	60.5	19.4

2.3 plants, soils and sites of the experiment

Seed collection of rice OM 18, corn DK9901 and mungbean ĐX 208 that had healthy, good disease resistance and high yield were taken from Institute for Agriculture of Moosanto company, Vietnam. Application of different fertilizer was presented in Table 2 & 3. The farm method was followed by local tillers and harvests during july of 2021 for three crop kinds. Two soil types of inside and outside the dike at three communes (Long Binh, Khanh Binh and Khanh An) were used during the experiment of three plants. the Cd content of the soil inside the dike was higher than that of soil outside the dike. Because the soil outside the dyke is alluvial during flood seasons and planted two seasons. In contrast, there was no the alluvial deposition and cultivated three crops for the soil inside the dyke. Thirty Soil samples were collected from inside and outside the dike at three communes which were collected at 20 cm of the soil depth for analysing physico-chemical characteristics. It was taken ten days before designing the experiment (Table 1). Soil samples were taken the initial and final experimental site and stem and seed samples were taken at the end of the crop for determining the Cd concentration. The phycical – chemical details of soil samples were used by methods of Bray & Kurtz [12]. pH, total N, total and available P, exchangeable K. Total Cd concentrations of all samples were used by Atomic Absorption Spectrophotometric (AAS). Yields (ton/ha) of rice, corn and mungbean were calculated after analysing the moisture percentage.

Table 2 effects of three different soils on the Cd absorption of three plants (experiment 1)

Treatment	Plants	commune	soil	Fertilizer (NPK, kg per ha)
1	Rice	Long Binh	Inside the dyke	100-60-50
2			outside the dyke	
3		Khanh Binh	Inside the dyke	
4			outside the dyke	
5		Khanh An	Inside the dyke	
6			outside the dyke	
7	Corn	Long Binh	Inside the dyke	250-90-60
8			outside the dyke	
9		Khanh Binh	Inside the dyke	
10			outside the dyke	
11		Khanh An	Inside the dyke	
12			outside the dyke	
13	Mungbean	Long Binh	Inside the dyke	40-50-60
14			outside the dyke	
15		Khanh Binh	Inside the dyke	
16			outside the dyke	
17		Khanh An	Inside the dyke	
18			outside the dyke	

Note: the irrigated water of all experimental treatments was the river water (no Cd pollution)

The analysis of variance for the significant differences of of treatments was done by Statgraphics Centurion XIX and the Multiple Range test of Duncan at LSD < 0.05 or < 0.01.

Table 3. The impacts of two lime ratios on the Cd uptake of three plants (experiment 2)

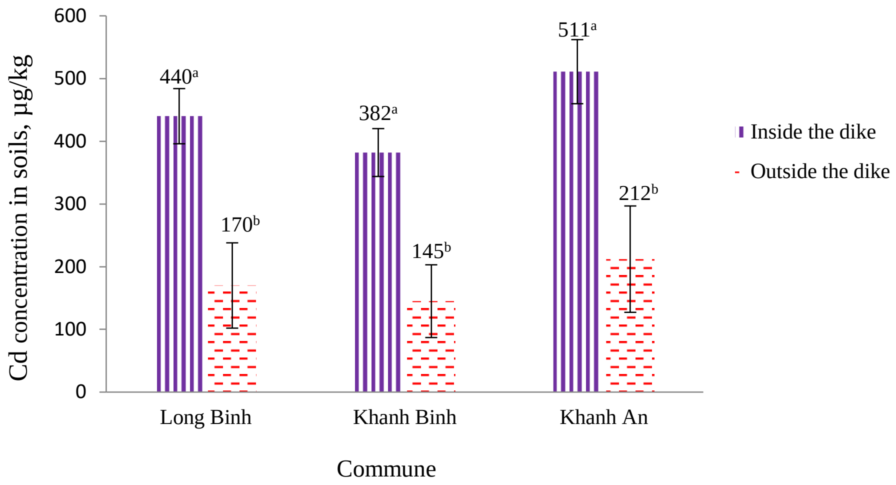
Treatment	Plants	Soil	Irrigation water	$CaCO_3$(ton / ha)	Fertilizer (N-P-K, kg/ha)
19	Rice	Inside the dike	River water	0	100-60-50
20				5	

21	Corn			0	250-90-60
22				5	
23	Mungbean			0	40-50-60
24				5	

Results and discussion

3.1 the Cd contamination of agricultural soil in three communes

Figure 1 Average Cd contents of agricultural soils



Results in Figure 1 obtained that Cd levels of the soil outside the dike valued from 145 to 210 mg/kg and 382 to 511 mg/kg for the soil inside the dike. Maximum Cd concentrations of the soil outside and inside the dike were 212 and 511 mg/kg at Khanh An comumne, respectively. On contrary, Minimum Cd concentrations of the soil outside and inside the dike were 145 and 382 mg/kg at Khanh Binh comumne, respectively. The soil Cd levels inside the dike were higher than two times compared to the soil Cd levels outside the dike in three surveyed comumnes and significant differences at $P_{value} \leq 0.05$. The soil Cd concentrations of three studied comumnes were so quite high dosage that it could be harmful to crops and human's health. The rice planted on the Cd polluted soil, which absorbed the Cd toxicant on stems and grains of crops from soil [13].

3.2 The influence of two different soils on pH of crop soil

Results of Figure.2 presented that soil pH of rice, corn and mungbean inside the dike of the previous and terminal experiment valued 4.5 to 5.8 and 4.2 to 5.4, respectively. The soil pH of the terminal experiment was lower than that of the initial experiment and significant difference at $P_{value} \leq 0.05$. Contrary to soil pH inside the dike, the soil pH of outside the dike was higher than that of the initial experiment and significant difference at $P_{value} \leq 0.05$. The above results can be explained as follows: the soil inside the dyke was not drained like the soil outside the dyke. Therefore, the number of H^+ ions accumulated more and more because plants took soil nutrients to release H^+ and fertilizers such as urea, phosphorus, etc.. also release H^+ which caused to decreas soil pH inside the dike [14].

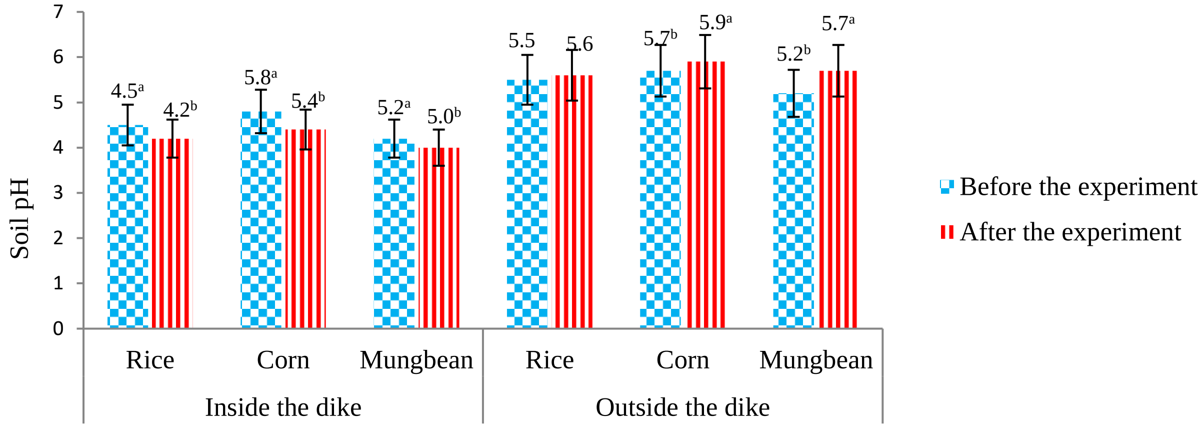


Figure 2 influences of various soils on the pH of soils at the previous and terminal experiment

3.3 The Cd accumulation of rice, maize and mungbean affected by lime.

The Cd accumulation of rice, corn and mungbean that varied from 51.9 to 130 ppb (stems) and 23.4 to 77.6 ppb (seeds), respectively, were significant differences at *1%*. The maximum Cd level of corn stems (130 ppb) and rice grains (77.6 ppb), Cd absorption in rice stems (51.9 ppb) and maize seeds (23.4 ppb) were the lowest, followed by the stem (117 µg/kg) and seed (37.6 µg/kg) of mungbean. (Table 4). The different conditions of agricultural soils and various plant types were the various Cd uptake of plants. The medium Cd concentration of stems and seeds of three plants at three comumnes varied from 64.7 to 159 µg/kg and 36.1 to 61.7 ppb, respectively. The medium Cd concentration of 159 ppb in stems and 61.7 ppb in seeds, which was the highest level at Khanh An comumne and the lowest value of stems (64.7ppb) and seeds (36.1 ppb) of Long Binh comumne (Table 4). The same results in Table 4 showed the Cd contents of stems (108 ppb) and seeds (35.7 ppb) of rice, maize and mungbean on soils the outside of dyke had higher than that of stems (90.9 ppb) and lower than that of seeds (56.6 ppb) compared to the soil inside the dike (Table 4). There were significant diffences of the Cd uptake of crop bodies when planted on different Cd pollution soils. The results in Table 4 could prove the same irrigation water kind and various soils, which had different Cd content of body each various plant and the maximum Cd absorption of rice seeds compared to rice and maize. The Cd store of plant seeds on soils inside the dyke was higher than that of soils outside the dyke. Because the Cd concentration of the soil inside the dike was polluted more than that of the soil outside the dike and significant various among plants (A) and commune (B) and soil (C) at 1%. The Cd contaminated soils raised the Cd accumulation of stems and seeds of plants [15]. The use Cd polluted soil reduced significantly the production and raised the Cd uptakeof plants [16].

Table 4 Influences of two soils on the Cd accumilation of three plants

Treatment	Cd concentration (ppb)	
	Stem	seed
Plant (A)		
-Rice	51.9^{b}	77.6^{a}
- Corn	130^{a}	23.4^{c}
- Mung bean	117^{a}	37.6^{b}
Commune (B)		
Long Binh	64.7^{c}	36.1^{b}
Khanh Binh	75.2^{b}	40.8^{ab}
Khanh An	159^{a}	61.7^{a}
Soil (C)		
- Outside the dike	108^{a}	35.7^{b}
- Inside the dike	90.9^{b}	56.6^{a}
F_{test} (A)	**	**
F_{test} (B)	**	**
F_{test} (C)	**	**
F_{test} (AxB)	**	**
F_{test} (AxC)	ns	ns
F_{test} (BxC)	ns	**
F_{test} (AxBxC)	ns	ns
CV (%)	26.6	37.8

Note: ns = insignificant differences,** significant difference at $P_{value} \leq 0.01$.

3.4 The influence of lime on pH of soils

The soil pH varied from 4.8 to 5.4 of without lime treatments and 5.2 to 6.8 of lime amended treatments (5.0 tons per ha) which increased from 5.2, 6.2 to 6.8 for rice, mungbean and corn compered to non lime treatments, respectively (Figure 3). The soil pH augmented significantly at lime amendment treatments compared to non lime application treaments in the final experiment. The application of 5.0 tons $CaCO_3$ per ha had the highest pH (6.8) of corn and the lowest value (4.8) of rice at the without $CaCO_3$ treatment (Figure 3). The Cd absorption of rice, maize and mungbean was adequately different among three various plant types with two rates of 0.0 and 5.0 tons $CaCO_3$ per ha. The lime amendment for agricultural soils raised the pH of farm soil after six weeks [17, 18]. The lime application both raised soil pH and lessened the Cd uptake of cops [19, 2]. The high pH of crop soils that could inhibit the Cd absorption of plants. Because, the movability and bioavailability of soil Cd was reduced by the lime [20, 21].

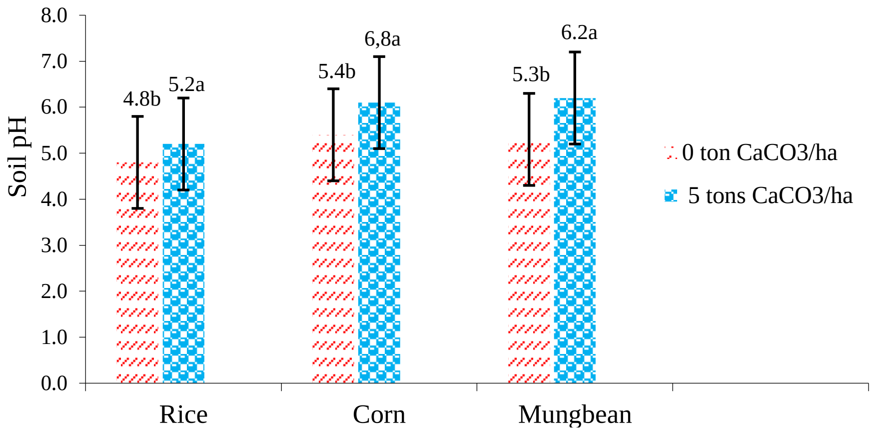


Figure 3 The influence of $CaCO_3$ on soil pH at the harvest

Table 5 Influence of $CaCO_3$ ratios on the Cd accumulation of three plants

Treatment	Cd concentration (µg/kg)	
	Stem	Seed
Plant (A)		
-Rice	61.3^{b}	87.0^{a}
- Corn	104^{a}	12.3^{c}
- Mungbean	93.2^{ab}	25.9^{b}
Lime (B)		
- 0.00 ton CaO/ ha	159^{a}	76.4^{a}
- 5.00 tons CaO/ ha	74.8^{b}	37.4^{b}
F_{test} (A)	**	**
F_{test} (B)	**	**
F_{test} (A x B)	**	**
CV(%)	25.9	25.4

Note: ** significantly different at 1%.

The Cd hoard of three plant bodies varied from 61.3 to 104 µg/kg in stems and 12.3 to 87.0 µg/kg in seeds. The Cd content of Corn stems (104 µg/kg) was the maximum level, followed by the munbean stems (93.2 µg/kg) and the minimum Cd concentration of the rice stems (61.3 µg/kg) (Table 5). On the contrary, the highest Cd concentration of rice grains was 87.0 µg/kg, followed by mungbean seeds (25.9 µg/kg) and the minimum Cd content of corn seeds (12.3 µg/kg) and significant difference at $P_{value} \leq 0.01$ (Table 5).

No lime amendment treatments achieved the average Cd contents of 159 µg/kg (stems) and 76.4 µg/kg (seeds) and stems (74.8 µg/ kg) and seeds (37.4 µg/kg) of 5.0 tons $CaCO_3$ per ha (Table 5). There was significant variousness between the without lime application and 5.0 tons $CaCO_3$ per ha of the Cd concentration in stems and seeds. The average Cd levels of three plants of control treatments (No $CaCO_3$ amendment) were higher two times than those of lime amendment treatments (5.0 tons $CaCO_3$/ha and significant difference at $P_{value} \leq 0.01$ (Table 5). The Cd absorption of crops was sufficiently affected by the low pH due to react among Fe and Al hydroxide and the soil Cd toxicant [22]. The reverse relation between the pH and Cd accumulation of plants that may raised significantly soil pH values [23]. The lime supplementary increased the soil pH, lessened the Cd uptake and increased crop yield [24].

3.5 Effects of two lime ratios and soil types on the yield of three plants

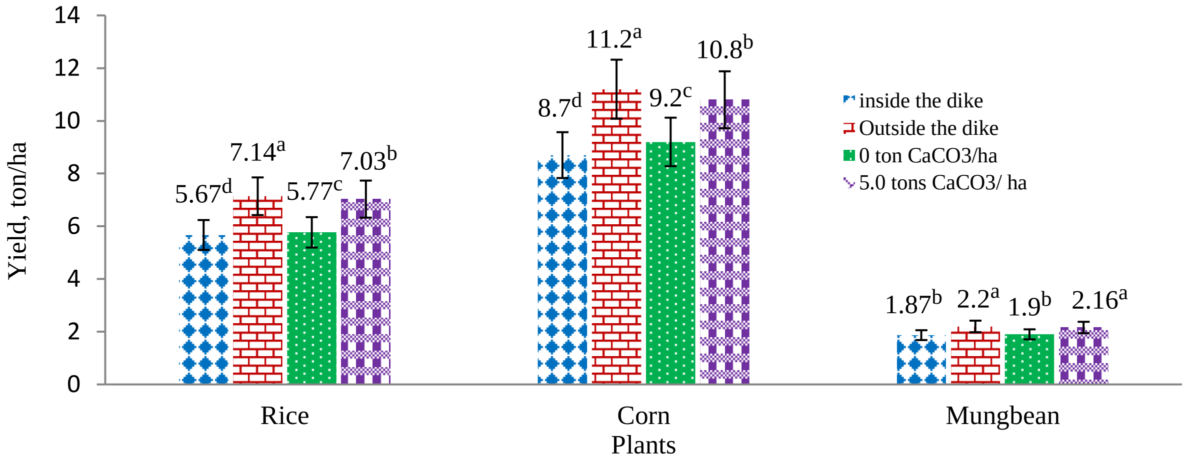


Figure 4 Influences of soil and lime on yields of three plants

Results in Figure 4 showed that average yields of rice of three communes ranged from 5.67 to 7.14 t/ha. the maximum rice production was 7.14 tons per ha at treatments of the soil outside the dike, followed at 5.0 tons $CaCO_3$/ha (7.03 t/ha), without lime amendment (5.77 t/ha) and minimum rice production (5.67 t/ha) of the soil inside the dike. the corn yield, which varried from 8.7 tó 11.2 tons/ha attained the highest values (11.2 tons/ha) of the soil outside the dike, following 5.0 tons $CaCO_3$/ha treatment (10.8 tons/ha), 9.2 tons/ha for without lime application and the lowest yield (8.7 tons/ha) of the soil inside the dike (Figure 4). The same results, the maximum and minimun mungbean yields of the soil outside and inside the dike were 2.2 and 1.87 tons/ha, respectively and significantly different at 5% (Figure 4). In generally, the rice, corn and mungbean production had the best results at treatments of the soil outside the dike, folowing 5.0 tons $CaCO_3$/ha amended treatments and the lowest yield of without lime and the soil inside the dike treatments, respectively. The above results can be explained as follows: The Soil outside the dyke had the lower Cd content than that of the soil inside the dyke, so the Cd toxicity was less harmful to plant growth, help plants to have a higher yield compared to the soil inside the dyke. The lime application raised the soil pH and Cd immovability and increased the production of plants [25]. Crops were cultivated on Cd contaminated which inhibited the growth and yield of plants [26, 27]. The soil pH Increase and the Cd movability decrese raised the crop yield by using the lime amendment [28].

Conclusion

Cadmium toxicant has really been a serious hazard to food safety and the health's human. High Cd contents of plants crops lessen the growth and field yield. This research's outcome brilliantly demonstrated that rice seeds had the highest Cd concentration, following mungbean seeds and the lowest Cd level of corn seeds. The highest Cd concentration of crop seeds was in Khanh An and the lowest Cd level of plant seeds in Long Binh commune. The amendment of 5.0 tons $CaCO_3$/ha had the Cd hoard of stems and seeds of three plants which was lower than without lime application. The highest yield of three plants reached at the soil types outside the dike, following the $CaCO_3$ application of 5.0 tons/ha and the lowest yield of without lime and the soil inside the dike for all of three plants. The important discovery of the research discovered the Cd store and yield of rice, corn and mungbean had the better value when planting on the soil outside the dike and 5.0 tons $CaCO_3$/ha. The lime addition of 5.0 tons $CaCO_3$ / ha with the soil outside the dike was the perfect pathway to lessen the Cd accumulation and raise yield of crops.

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