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Influences of lime and irrigation water on arsenic accumulation of rice, maize and mungbean in the nethouse condition

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Abstract

The essential goal of this study discovered effects of lime ratios, agricultural soils and irrigation water types on the arsenic (As) uptake of rice, maize and mungbean in the nethouse condition. Two nethouse experiments had three plant types of rice, maize and mungbean with two soils of inside and outside the dyke, two irrigated waters of 0.0 and 200 µg As/L and three different lime ratios (0, 7.0 and 9.0 tons CaO/ha). The whole treatments were twenty one (12 treatments of experiment 1 and 9 of experiment 2) and 4 repeats. Results of this study showed that the lime application raised both soi pH and crop yield . The As absorption of plant bodies in stems and seeds at inside the dyke was higher from 67.8 to 68.3% than those of outside the dyke, respectively. Arsenic contents of stems and seeds at treatments of 200 µg As/ L irrigation water were higher from 81.5 to 89.4 % than those of non As irrigation water, respectively. The lime supplementation of 7.0 and 9.0 tons CaO per ha reduced the As accumulation of stems and seeds of rice, maize and mungbean lower than without lime supplement from 38.6 (stems) and 54.5 (seeds). Mungbean absorbed the highest As, followed by rice and maize was the lowest As value. However, the lime supplementation of 9.0 tons CaO/ha had so high soil pH of soil that restricted the growth and yield of crops. More lime ratios need to sudy for more new details and new discovery of positive effects of this study.

Keywords: Arsenic, lime, maize, mungbean, rice

Introduction

Rice, maize and mungbean, which are mainstay sources of foods in Vietnam and Asian people have been cultivated in Asian countries and a supplementing source of essential nutritives for human.The recent studies were found out the As accumulation on stems and seeds of rice, maize and mungbean [1], [2]. The agricultural cultivation has been planting and watering on As contaminated soils and waters, which asorbed the high As content of their stems and seeds and reduced production of plants. Local tillers irrigated for their fields by deep wells, which were mainly the As pollution source to raise As concentration of soils and products of agriculture [1], [3], [4], [5]. Relations between soil As content of pollution irrigation waters, soils and seeds were the positive correlation coeffciens [6]. The As concentration of fourty deep well water samples exceeded WHO and Vietnam standards (100 to 461 ppb). Local tillers (30- 92.6%) were been using the deep well water to watering for their crops [1], [6]. When tills of rice, mungbean and maize that absorbed by the high As accumulation of stems and seeds came from As contaminated soils and irrigation water [7], [8]. Rich calcium materials, which may increase soil pH, reduce the As mobility of soil and contribute to the soi fertility for plants were both the As immobilization of soil and As accumulation by plants [9], [10]. Furthermore, the application of lime combined with inorganic fertilizers and river water irrigation are the best way to reduce the As accumulation of agricultural soils which causes to raise the As accumulation of plants [11], [12]. Co-application of lime and NPK fertilizer, which raised pH and precipitated As element in crop soils was the high technology for the effective and unshaken productivity [13]. The primary aim of this study rated impacts of lime, As polluted soils and irrigated waters on the As accumulation of rice, maize and mung bean in the nethouse condition.

Materials and Methods

Nethouse experiments was designed at at the net house of An Giang university during January to jun, 2021. Eighty four plastic pots that were taken experiment 1: three plant types x two irrigation water types x two soil types x four repeats + experiment 2: three plant types x three lime ratios x four repeats = 84 were 25 cm in diameter and 25 cm in height. Three kg soils per pot was collected from Phuoc Hung. The next stage, Lime was mixed the soil before 15 days sowing with NPK fertilizer in Table 4. There were 21 different treatments for two experiment (experiment 1 and 2 with twelve and nine treatments, respectively). Twelve treatments of the experiment 1 included: R1, R2, R3, R4, M5, M6, M7, M8, MB9, MB10, MB11 and MB12 and nine treatments of experiment 2: RL1, RL2, RL3, ML4, ML5, ML6, MBL7, MBL8 and MBL9 presented in Table 3 & 4. Two irrigation waters (i) without As contamination water (river water), (2): The As contamination irrigation water of 200 µg As/ L (diluted 200 µg As + without As contamination water = 1 litre) in the nethouse experiment condition. Two nethouse experiments, which were amended for three plants of rice, maize and mungbean had: (experiment 1) two irrigation water types (without As polluted water and water of 200 µg As/ L) and two soil types (inside and outside the dyke) in Table 3; (experiment 2) three CaO rates (0.0, 7.0 and 9.0 t/ ha), the soil inside the dyke and irrigted water of 200 µg As/L (dilute 200 µg As + without As contamination water = 1 litre) in Table 4.

Table 1. The growing of three plant types in the nethouse condition (following local tillers)

No.	**Plants**	**Pot diameter (cm)**	**Seeds/pot**	**Soil weight/pot (kg)**	**Manures (kg/ha)**
1	Rice	25	10	5	$100N-60P_2O_5-30K_2O$
2	Maize	25	2	10	$250N-90P_2O_5-60K_2O$
3	Mungbean	25	2	5	$40N-60P_2O_5-50K_2O$

Seeds of rice OM5451, maize DK 888 and mungbean ĐX 208 collected from Institute for Agriculture of Loc Troi Group, An Giang, Vietnam. The growing technology and fertilizer rates is shown in Table 1. The crop harvest was from the first to end of jun, 2021 for three plant types. Samples of two soil types were taken from inside the dyke and outside the dyke at An Phu district, which were collected in the soil depth (0-20 cm) for the nethouse experiment. The physico-chemical characteristics of first soil are shown in Table 2.

Table 2. Physical-chemical properties of water and soil of the initial experiment

Parameters	Value	Parameters	Value
Silt (%)	55.6	Total N (%)	0.04
Clay (%)	12.7	Available P, mg/kg	1.12
Sand	31.7	Exchangeable K meq/100g	0.10
Soil texture	Silt sand loam	Organic matter (%)	0.71
Soi pH inside the dike	4.75	Total As (soil inside the dyke), mg/kg	54.6
Soil pH outside the dike	5.52	Total As (soil outside the dyke), mg/kg	12.5

Table 3. The influence of waters and soils on the As uptake of rice, maize and mungbean (experiment 1)

Treatment	**Plants**	**Soil**	**Irrigation waters (As content, µg L^{-1})***
R1	Rice	Inside the dyke	0 (unpolluted water)

R2			200 (polluted water)
R3		outside the dyke	0 (unpolluted water)
R4			200 (polluted water)
M5	Maize	Inside the dyke	0 (unpolluted water)
M6			200 (polluted water)
M7		outside the dyke	0 (unpolluted water)
M8			200 (polluted water)
MB9	Mungbean	Inside the dyke	0 (unpolluted water)
MB10			200 (polluted water)
MB11		outside the dyke	0 (unpolluted water)
MB12			200 (polluted water)

Note: The As contamination irrigation water of 200 µg As/ L (dilute 200 µg As + without As contamination water = 1 litre)*

Soil samples was collected before and after each experimental pot. Plant samples were collected at the harvest. Properties of soil samples were determined by using methods for texture, total As, pH, organic matter, total N, available P and exchangeable K contents. Soil pH was determined by pH meter Total As concentrations of all samples were determined Atomic Absorption Spectrophotometric (AAS). Yields (ton/ha) of rice, maize and mungbean were calculated after analysing the moisture percentage. 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 4. The influence of lime rates on the As accumulation of rice, maize and mungbean (experiment 2)

Treatment	**Plants**	**Soil**	**Irrigation water**	**Lime (ton CaO/ ha)**
RL1	Rice	Inside the dyke	200 µg As/ L) (contaminated water)	0
RL2				7
RL3				9
ML4	Maize			0
ML5				7
ML6				9
MBL7	Mungbean			0
MBL8				7
MBL9				9

Results And Discussion

3.1 Effects of soil and irrigation water on As uptake of rice, maize and mungbeans

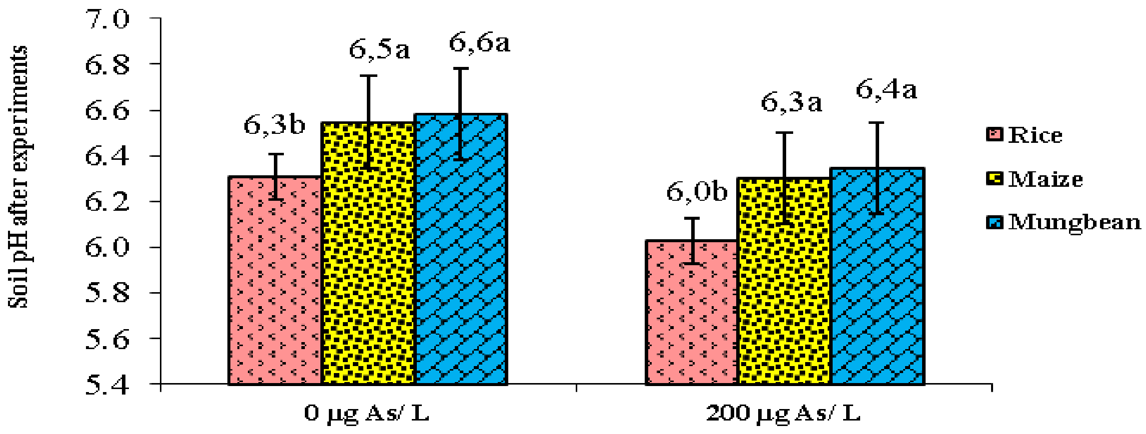

Fig.1. Effect of different irrigation waters on soil pH at the end of experiment

Results of Figure.1 showed that the average soil pH of rice, maize and mungbean ranged from 6.3 to 6.6 for the 0.0 µg As/L irrigation water treatments and 6.0 to 6.4 for the 200 µg As/L irrigation water treatments. The average soil pH of rice, maize and mungbean in the 200 µg As L^{-1} irrigation water treatments was lower than that of rice, maize and mungbeans in the 0.0 µg As/L irrigation water treatments (Fig.1). The results in Fig.1 showed that soil pH of the end of the whole experiments increased adequately compared to the initial soil pH of the experiment. In addition, the cultivation method of each crop also had the impact on soil pH. The soil pH of rice treatments tended to be lower and significantly different from the soil pH of maize and mungbeans treatments. Different types of plant and the As presence of irrigation water reduced the soil pH (Fig.1). Arsenic elements of the polluted irrigation water were forms of arsenate (H_2AsO^{4-}, $HAsO^{42-}$) or arsenic (H_3AsO_3) in soils and released H^+ which caused to reduce the soil pH [14]. Arsenic concentration in soil and plants were affected by irrigation water conditions and soi pH. The As availability and movement in soil was determined by the soil pH which was affected by the high or low As concentration of crop irrigation water [15].

Table 5. Effects of different soils and irrigation water on As centents of rice, maize and mung bean

Treatment	As contents (µg/ kg)	
	Stem	**seed**
Plant (A)		
-Rice	355^b	166^b
- Maize	298^c	102^c
- Mung bean	591^a	382^a
Soil (B)		
- Inside the dike	590^a	341^a
- Outside the dike	190^b	108^b
Irrigation water (C)		
- 0 µg As L^{-1}	104^b	50.6^b
- 200 µg As L^{-1}	562^a	479^a

F (A)	**	**
F (B)	**	**
F (C)	**	**
F (Ax)	**	ns
F (AxC)	ns	**
F (BxC)	**	**
F (AxBxC)	ns	ns
CV (%)	22.7	11.3

*Note: ns = insignificant differences,** significant difference at 0.01%.*

The results in Table 5 showed that stems and seeds As contents of rice, maize and mungbean, which ranged from 298 to 591 µg/kg and 102 to 382 µg/kg, respectively were significantly different at 1% among treatments. The highest As contents of stems (591 µg/kg) and seeds (382 µg/kg) obtained at mungbean treatments, Arsenic accumulation in green beans in stem and seeds is highest, followed by the stem (355 µg/kg) and seed (166 µg/kg) of rice and the lowest As value of the stem (298 µg/kg) and seed (102 µg/kg) of maize (Table 5). The same conditions of farming soil and irriagion water had the diffenent As absorption of plant bodies when different crop types. The average As content of stems (590 µg/ kg) and seeds (341 µg/ kg) of rice, maize and mungbean on soils the inside of dyke had higher than those of stems (190 µg/kg) and seeds (108 µg/kg) compared with the soil the outside of the dyke (Table 5). The As accumulation of rice, maize and mungbean bodies in stems (562 µg/kg) and seeds (479 µg/kg) in 200 µg As/L irrigated treatments were higher than 81.5% in stems and 89.4% in seeds those of unpolluted irrigation water treatments. There were considerable diffences of the As accumulation of plant bodies when watering for crops by unpolluted or polluted water. The results of Table 5 could interpret the same soil and irrigation water type, which may absorb different As levels of plant bodies for each different plant. The highest As accumulation of stems and seeds of mung bean were compared by those of rice and maize. Furthermore, the As accumulation of stems and seeds of plant bodies on soils inside the dyke were higher than those of soils outside the dyke. Because the As cocentration of the soil inside the dyke was contaminated more than that of the soil outside the dyke and significantly different among plants (A) and soil (B); soil (B) and water (C) at 1% level. According to prior studies proved that As polluted water irrigation not only increased the soil As concentration but also raised As accumulation of stems and seeds of crops [16], [6]. The use Arsenic polluted water irrigation was already lessening the yield and increasing gradually the arsenic accumulation of field soils [17].

3.2. Effects of lime ratios on As uptake of rice, maize and mungbean.

The soil pH, which ranged from 6.1.to 7.8 for all treatments raised from 6.1, 7.2 to 7.3 (rice), 6.1, 6.8 to 7.5 (maize) and 7.2, 7.6.to 7.8 (mungbean) at 0.0, 7.0 to 9.0 tons CaO/ ha, respectively and LSD < 0.01 (Fig. 2).The soil pH raised sufficiently in lime addition treatments compared without lime treaments in the initial experiment, which obtained the maximum pH (7.8) of mungbean at the MBL9 (9.0 tons CaO/ha) and the minimum pH (6.1) of maize at the ML4 (0.0 tons CaO/ ha. The As accumulation of plant bodies of rice, maize and mungbean had was completely various among three plants with three lime ratios of 0.0, 7.0 and 9.0 tons CaO/ha. The lime supply for farming soils may raise the soil pH of fields from three to six lime amended weeks being conditional on lime types [18]. The lime supplementation not only increases soil pH but also reduces the As accumulation of plants and increases crop yield [19]. The movability and bioavailability of soil As could raise adequately when reducing soil pH. Therefore, the immovability and bioavailability decrease of soil As by the lime supplementation which has been the indefectible technology [20], [21].

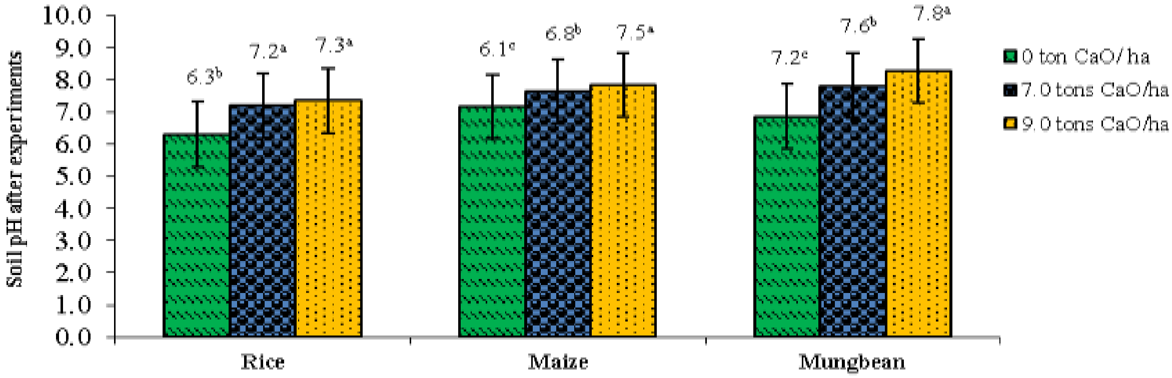

Fig.2. Effect of different lime ratios on soil pH after the experiment

Table 6. Effects of lime ratios on As centents of rice, maize and mungbean

Treatment	As contents (µg/kg)	
	Stem	Seed
Plant (A)		
-Rice	649^{b}	422^{b}
- Maize	113^{c}	104^{c}
- Mungbean	$1{,}240^{a}$	659^{a}
Lime (B)		
- 0.00 ton CaO/ ha	998^{a}	589^{a}
- 7.00 tons CaO/ ha	617^{b}	271^{b}
- 9.0 tons CaO/ ha	613^{b}	268^{b}
F (A)	**	**
F (B)	**	**
F (A x B)	**	**
CV(%)	21.7	18.9

*Note: ** significant difference at 1% ($p \leq 0.01$).*

The As accumulation of stems and seeds of mung beans, which was the highest As concentration were 1,240 and 659 µg/kg, followed by the stem (649 µg/kg) and seed (422 µg/kg) of rice and the lowest As value of the stem (113 µg/ kg) and seed (104 µg/ kg) of maize was completely various among treatments at 1% (Table 6). Similarly, the highest As content of plant bodies, which obtained at non lime supplement had average As concentration of 998 µg/kg (stem) and 589 µg/kg (seed), followed by the stem (617 µg/ kg) and seed (271 µg/kg) of 7.0 tons CaO/ha application and the lowest As value of the stem (613 µg/ kg) and seed (268 µg/kg) of 10.0 tons CaO/ha application was completely various among treatments at 1% (Table 6). When comparison between the 7.0 and 90.0 tons CaO/ha treatments which was insignificant various between 7.00 and 9.0 tons CaO/ha about the As concentration of plant bodies. General results proved that As uptake of mungbean was the highest level, followed by rice and the lowest As value of maize. Application of 7.0 and 9.0 tons CaO per ha reduced the As accumulation of stems and seeds lower than in the without lime treatments. The As accumulation of plants was adequately influenced by the lowe pH because of the reaction between Fe and Al hydroxide and soil As kinds [22]. Negative correlation between the pH and As hoard of plants which could increase significantly soil pH values [23]. The lime application may raise the soil pH which is the main causeto reduce the As uptake of plants because of the immovability of soil As [24]. Lime amendment raised the agricultural soil pH to be contingent upon lime rates [25].

3.3. Effects of lime ratios on yield components tof rice, maize and mungbean

All highest 1,000 seeds weights of rice (27.0 gr), maize (270 gr) and mungbean (100gr) in RL2, ML2, ML3 and MBL2 treatments were attained by the amendment of 7.0 tons CaO/ha. The followed values were attained by RL3 (25.4 gr) of rice and mungbean (90.9 gr) in treatments of 9.0 tons CaO/ha. The lowest weight of rice, maize and mungbean was gotten by 24.6, 260 and 91.8 gr at RL1, ML1 and MBL1 treatments (no lime)(Table 7). Similar to the 1,000 seeds weight, number of pod per pot of rice, maize and mungbean raised significantly (at 5% level) with increased lime rates from 0.0, 7.0 to 9.0 tons CaO/ha. the 1,000 seeds weight of three plants was adequately impacted by the lime supplementation. All highest values of 1,000 seeds weight of three plants reached at 7.0 tons CaO/ha treaments and the lowest values were at none lime treatments (Table 7). Results in Table 7 presented that number of seeds per pod of rice, maize and mungbean had sufficiently influenced by various lime rates and sufficiently diffences at 5% level.. The the highest values of three plants were attained by the lime application of 7.0 tons per ha, followed at 9.0 tons/ha and the minimum value at without lime supplementation (0.0 tons CaO/ha (Table 7). Plants were tilled on As polluted soils and were irrigated by As polluted waters which may lessen the mature and production of fields [4], [5]. The line amendment, which aimed to increase soil pH and the As immovability of soil and may increase the yield of fields [26]. However, application of high lime level increase could increase to unsuitable pH for growing of plants [27].

Table 7. Yield components and production of rice, maize and mungbean affected by lime ratios

Treatment	1,000 seeds weight (gr)	No.of pods/ pot	No.of seeds/ pod
-Rice (A)			
- 0.00 ton CaO/ha	24.6^{c}	25.6^{a}	59.1^{b}
- 7.00 tons CaO/ha	27.0^{a}	25.0^{a}	60.9^{a}
- 9.0 tons CaO/ha	25.4^{b}	21.6^{b}	59.0^{b}
Maize (B)			
- 0.00 ton CaO/ha	260^{b}	3.05^{c}	367^{b}
- 7.00 tons CaO/ha	270^{a}	4.00^{a}	482^{a}
- 9.0 tons CaO/ha	270^{a}	3.55^{b}	483^{a}
Mungbean (C)			
- 0.00 ton CaO/ha	90.8^{b}	30.3^{c}	10.0^{c}
- 7.00 tons CaO/ha	100^{a}	34.0^{a}	12.9^{a}
- 9.0 tons CaO/ha	91.9^{ab}	31.8^{b}	11.1^{b}

F(A)	*	*	*
F(B)	*	*	*
F(C)	*	*	*
CV_A(%)	5.80	4.50	6.80
CV_B(%)	3.10	17.0	6.10
CVc(%)	1.50	8.80	11.9

*significant difference at 5% (P<0.05).

Conclusion

Results of this study powerfully proved that application of 7.0 and 9.0 tons CaO per ha reduced the As accumulation of stems and seeds of rice, maize and mungbean lower than without lime supplement. The amendment of 7.0 tons CaO per ha combined with the As unpolluted water irrigation was the best way to decrease the As accumulation. The highest yield of rice, maize and mungbean reached at lime amendment treatments of 7.0 tons CaO per ha in the agricultural cultivation on As polluted soils and the As polluted water irrigation. The new discovery of this study found out the As accumulation of stems and seeds mungbean of was the highest value when comparing to those of rice and maize. The amendment of 9.0 tons CaO/ha had so high soil pH of soil that restricted the growth and yield of crops.

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