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Arsenic Uptake and Yield of Maize and Mung Bean Affected by Lime, Soil and Irrigation Water

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Abstract

Reducing As accumulation and increasing yield of maize and mungbean were this study's main goals. Two field experiments included 3 factors (plant, soil and irrigation water) with 14 treatments (experiment 1: 6 treatments and experiment 2: 8) and 4 replications. There were three different lime ratios (0, 5.0 and 10.0 tons CaO/ha), two soil types (the inside and outside dike soil) and two irrigation water types (deep well water and river water). The As accumulation of stems and seeds of maize were lower than that of stems and seeds of mungbean from 50.4 to 91.1% (stems) and 69.9 to 79.6% (seeds). Co-application of 5.0 tons CaO combined with NPK, river water irrigation and planted on the soil outside the dike were the highest As decrease and yield raising of maize and mungbean. The soil pH was strongly raised at the application of 10 tons CaO/ha which caused to lessen the production of maize and mungbean. Application of 5.0 tons CaO per ha combined with river water irrigation and planting on the outside dike soil would be introduced this technique to local farmers.

Key words: Arsenic, deep well, lime, maize, mungbean

1. Introduction

Corn (*Zea mays* L) has been cultivated in southeast Asia countries, which is an important food resources food for humans (Rosas et al., 2014). The prior studies of Chuong et al., 2021; Khan et al., 2018 showed that mung beans are one of the important food sources for supplementing highly vitaminic and mineral nutrients for humans. The yield component and yield of mung beans has reduced by the As contamination of soils and deep well water. The As absorption of maizes, which were planted on soils and irrigated waters of the high As contamination were the main cause to raise the As concentration of seeds and stems of maizes (Liu et al., 2018; Zhao et al., 2018). The prior research of Fu et al., (2016) also proved that As-resistant maize may decrease As uptake of its stems and seeds. According to recent study of Nguyen Van Chuong, (2011) showed that relationship between As content of soils, deep well waters and rice grains were significantly high correlation coeffciens. All deep well water samples of eight comumnes in An Phu, which ranged from 100 to 461 µg As/L surpassed allowable standards of WHO and Vietnam. Furthermore, the wide range of 30 to 92.6% of local farmers have used the As contaminated water to irrigate their fields (Nguyen Van Chuong and Huynh Tan Hung, 2021). The As contamination of crop soil and irrigation water which has been used to cultivate for a long term in Phuoc Hung commune was really lessening the crop production and was dangerous to the human health (Nguyen Van Chuong and Huynh Tan Hung, 2021). The maize and mung bean, which were significantly absorbed the high As toxicity cultivated on both As contaminated soil and irrigation water (Ruíz-Huerta et al., 2017, Chuong et al., 2021). The As concentration of maize and mungbean seeds, which surpassed allowable standards may be dangerous to the human health. (Ali et al., 2013). Co-application of lime, inorganic fertilizers combined with river irrigation water are the best method to lessen the As content of soil and its absorption by maize and mungbean (Requejo & Tena, 2012, Moon et al., 2014). The lime Amendment with inorganic fertilizers, which raise soil pH and fixed As poison was the perfect technology for the efficient and sustainable agricultural production (Bolan & Duraisamy, 2015). The precipitation and reducing agent of soils As were amended by lime and organic matters, which raised the yield of crops and reduced the As uptake of stems and grains of crops (Cu et al., 2014; Chuong & Chinh, 2018;). The main objective of this research found out effects of lime rates, crop soils and irrigated waters on the As uptake and yield of maize and mung bean.

2. Materials and Methods

The field study was conducted at farmer’s field in Phuoc Hung, An Phu district, An Giang province during January to June, 2021. Two different types of soil samples were collected inside dike (deep well water), and outside dike (river water) at Phuoc Hung, An Phu district were taken from 0 to 20 cm in the soil depth. The soil texture and chemical properties are presented in Table 1.

Different ratios of lime, inorganic fertilizer and irrigation water kinds: There were two field experiments, which were used in both maize and mung bean experiments included: (i) three lime rates (0.0, 5.0 and 10.0 tons CaO/ha) and inside the dike in Table 2; (ii) two irrigated water (the deep well water and river water) and two soil types (inside the dike and outside the dike) in Table 3. There were on the whole 14 (6+8) treatments association as (i) M1a, M2a, M3a, MB1a, MB2a, MB3a and (ii) M1b, M2b, M3b, M4b, MB1b, MB2b, MB3b and MB4b. The experimental arrangement was carried out in a randomized complete blocks order with four repeats.

Cultivation of crops: Seed sprouting and collection: Wholesome seeds of Maize DK 888 and Mungbean ĐX 208 were planted during the experiment that were taken from Loc Troi group Research Institute, An Giang,Vietnam. The selected seeds that were soaked about 24 hours kept in the pocket began to sprout after 48 hours and germinate after 72 hours. Fifty-six plots with the whole area of experiments was 560 m^2 (0.5 m in width x 20 m in length per each repeat x 4 repeats x 14 treatments = 560 m^2). Two seeds of maize and mung bean were sown per hole with the distance of 50 cm x 30 cm (single row)

Application of lime, fertilizer and irrigation water: Three lime levels that were 0.0, 5.0 and 10.0 tons CaO per ha for applying the maize and mung bean were applied 15 days before planting. Two levels of NPK, which were 250kgN-90kgP_2O_5-60kg K_2O per ha for maize and 40kg N- 50kg P_2O_5 -60kg K_2O per ha for mung bean were fertilized in the whole treatments according to local farmers (Table 2). Two types of irrigated water included the river water (Arsenic unpollution) and deep well water (Arsenic pollution) in Table 3.

Collection of Water, Soil and plant sampling: four water samples were collected from Hau river and deep wells, which located within the experimental area. Soil samples was taken before and after each repeat of each experimental treatment and plant samples were collected at the harvest.

Sample analysis: Soil (inside and outside the dike) samples were analyzed for texture, total As, pH, organic matter, total N, available P and exchangeable K contents. Soil pH was determined by pH meter and Soil properties were determined by Piper, 1950; Page et al. 1982. Water (river and deep well water) and plant (stem and seed) samples were determined the total As. Water, soil, stem and seed samples were determined for total As contents by Atomic Absorption Spectrophotometric - Agilent 280FS AAS (Wei and Chen, 2002, 2006). Maize and mung bean yields were recorded at tons per ha after counting the moisture percentage.

Table.1. Water and Soil properties before the field experiment (n=4)

Parameters	Value	Parameters	Value
Silt (%)	48.6	Total N (%)	0.07
Clay (%)	12.7	Available P, mg/kg	1.02
Sand (%)	38.7	Exchangeable K meq/100g	0.08
Soil texture	Silt sand loam	Total As (river water), µg/L	Negative
Soi pH inside the dike	4.01	Total As (deep well water), µg/L	697
Soil pH outside the dike	5.02	Total As (soil inside the dike), mg/kg	34.6
Organic matter (%)	0.61	Total As (soil inside the dike), mg/kg	11.5

Table.2. Co-application of lime and irrigated water of field treatments

Treatments	Plants	Fertilizers	Addition	Irrigation water
M1a	Maize	NPK	250kgN-90kgP_2O_5 -60kg K_2O/ ha	Deep well water (As polluted water)
M2a		NPK + lime	5.0 tons CaO + NPK	
M3a		NPK + lime	10.0 tons CaO + NPK	
MB1a	Mung bean	NPK	40kg N- 50kg P_2O_5 -60kg K_2O/ ha	
MB2a		NPK + lime	5.0 tons CaO + NPK	
MB3a		NPK + lime	10.0 tons CaO + NPK	

Table.3. Irrigation water and soil types of field treatments

Treatments	Plants	Soils	Irrigation water
M1b	Maize	Inside the dike	River water (As unpolluted water)
M2b			Deep well water (As polluted water)
M3b		outside the dike	River water (As unpolluted water)
M4b			Deep well water (As polluted water)
MB1b	Mung bean	Inside the dike	River water (As unpolluted water)
MB2b			Deep well water (As polluted water)
MB3b		Outside the dike	River water (As unpolluted water)
MB4b			Deep well water (As polluted water)

Data Analysis: The Microsoft Office Excel was used to calculate for means and standard deviations. Statgraphics Centurion XIX was used to analyse the variance of significant differences of treatments at $P_{value} < 0.05$ or $P_{value} < 0.01$.

3. Results and Discussion

Effect of lime on Soil pH: soil pH of lime amended treatments after the experiment, which increased from 6.3, 7.2 to 7.9 at 0.0, 5.0 to 10 tons CaO/ ha at maize treatments and 6.1, 6.8 to 8.0 at 0.0, 5.0 to 10 tons CaO/ ha at mung bean treatments, respectively (Fig.1), and significant differences at P < 0.01 (Fig. 3). pH values of after the experiment increased significantly when comparing to no lime amendment. The increase lime rate raised the soil pH at the end of experiments, which valued the highest pH (7.9) of maize at the M3a (10.0 tons CaO/ha) and the lowest pH (6.3) at the M1a (0.0 tons CaO/ha); lowest pH (6.1) at the MB1a (0.0 tons CaO/ha) and the highest pH (8.0) at MB3a (10.0 tons CaO/ha) of mung bean. The lime amendment increased the pH of agricultural soil after three to six lime applied weeks upon solid or liquid lime. According to Nguyen Van Chuong, (2011); Suswanto et al., (2007) showed that lime application raise the soil pH upon different lime ratios.

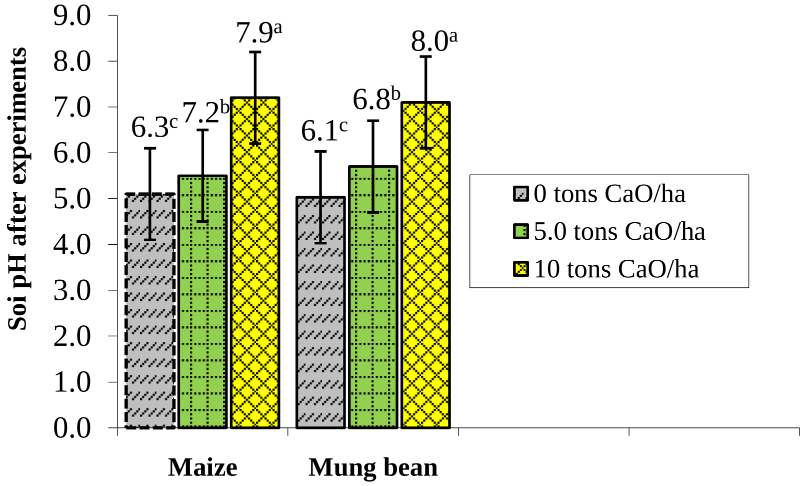

Fig.1. effect of lime and As contamination irrigation on Soil pH after experiment

Table.4. Effects of different lime ratios on As centents of maize and mung bean

Treatment	**As contents (µg/kg)**	
	Stem	**Seed**
Plant (A)		
- Maize	103[b]	114[b]
- Mung bean	1,140[a]	559[a]
Lime (B)		
- 0.00 ton CaO/ha	988[a]	579[a]
- 5.00 tons CaO/ha	607[b]	261[b]
- 10.0 tons CaO/ha	573[b]	221[b]
F (A)	**	**
F (B)	**	**
F (A x B)	**	**
CV(%)	23.9	16.9

** significant difference ($p \leq 0.01$).

The As contents of stems and seeds of maize and mung beans had significant differences between two plants with the different ratios of lime. Stems and seeds of mung beans, which had the higher As accumulation were 1,140 and 559 µg/kg compared to than those of the maize As content of 103 and 114 µg/kg, respectively (Table 4). As contents of stems and seeds of maize and mung beans among different lime treatments also had significant differences at P< 0.01. The highest As concentration of the stems and seeds that reached at without lime treatments obtained average As contents of 988 µg/kg (stem) and 579 µg/kg (seed) compared to the lime treatments (5.00 and 10.0 tonsCaO/ha). However, there was insignificant differences between 5.00 and 10.0 tons CaO/ha about As contents in stems and seeds. Experimental results showed that As accumulation of maize was lower than that of mung bean in stems and seeds. Furthermore, lime treatments (5.00 and 10.0 tons CaO/ha) were lower As uptake of stems and seeds than in the control treatments (without lime). The As uptake of plants was affected by soil pH and low pH (<5.5) could increase the movability and bioavailability of soil As. Application of lime raised the soil pH, soil As immovability and reduced the soil As bioavailability (Quazi et al., 2011; Chatterjee et al., 2013). Arsenic uptake of crops had significantly affected by the lowe pH (<5) because the oxyhydroxide compounds of both Fe and Al metals reacted As types of agriculture soils (Signes-Pastor et al., 2007). Negative relations between the high pH (>5.5) and As accumulation of crops which could become insoluble and reducible the As uptake of plants (Chuong et al., 2021; Rafiq et al., 2017; Chandrakar et al., 2016).

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

Treatment	**As contents (µg/kg)**	
	Stem	**seed**
Plant (A)		

- Maize	288[b]	112[b]
- Mung bean	581[a]	372[a]
Soil (B)		
- Inside the dike	490[a]	241[a]
- Otside the dike	390[b]	208[b]
Irrigation water (C)		
- River	154[b]	54.6[b]
- Deep well	662[a]	379[a]
F (A)	**	**
F (B)	**	**
F (C)	**	**
F (A x B)	**	ns
F (A x C)	ns	**
F (B x C)	**	**
F (AxB x C)	ns	ns
CV (%)	32.7	15.3

ns = non significant difference ($p \geq 0.05$). ** significant difference ($p \leq 0.01$).

Arsenic contents of stems and seeds of maize and mung bean were significant differences among experimental treatments. Mung bean had the As accumulation of stems (581 µg/kg) and seeds (372 µg/kg) and were higher than those of stems (288 µg/kg) and seeds (112 µg/kg) of maize and significant differences at $P < 0.01$ (Table 5). Thereby, it was shown that under the same soil and water conditions, each plant was very different As accumulation in stems and seeds. Arsenic concentrations of stems (490µg/kg) and seeds (241 µg/kg) on the soil inside the dike were higher than those of stems (390 µg/kg) and seeds (208 µg/kg) in the soil outside the dike and significantly differents at 1% (Table 5). Above results may be explained that soil As contents inside the dike were more contaminated than the soil outside the dike. There were significant differences between plants (A) and soil (B); soil (B) and water (C) at 1% level. There was great differences from As contents of stems and seeds in river and deep well irrigation treatments. Arsenic concentrations of stems (662 µg/kg) and seeds (379 µg/kg) in deep well water treatments were about four times higher than that of river water treatments. Results of Table 5 showed that under the same soil and irrigated water conditions, the As accumulation of stems and seeds is also very different for each crop. In addition, As contents of stems and seeds of mung bean were higher than those of stems and seeds of maize. However, As contents of stems and seeds of maize and mung bean, which were planted on soils inside the dike and irrigated the deep well water were higher than those of soils outside the dike and irrigated the river water. The prior study of Chuong and Hung, 2021 proved that As contents of stems and seed of mung bean in deep well water irrigation treatments were higher than those of stems and seed in river water irrigation treatments. The long term use of As contaminated water for irrigation has caused the arsenic concentration in agricultural soil to increase gradually (Saldaña-Robles et al., 2018)

Table 6. Effects of different lime ratios on yield components and yield of maize and mung bean

Treatment	Biomass (gr/plant)	100 seeds weight (gr)	No.of pods/ plant	No.of seeds/ pod	Yield (ton/ha)
Maize (A)					
- 0.00 ton CaO/ha	153[b]	26.0	3.25	367[b]	8.20[c]
- 5.00 tons CaO/ha	165[a]	27.2	4.00	482[a]	10.8[a]
- 10.0 tons CaO/ha	159[b]	27.2	3.75	483[a]	9.70[b]
Mung bean (B)					
- 0.00 ton CaO/ha	47.7[b]	9.77[b]	30.3	10.0	1.87[c]
- 5.00 tons CaO/ha	52.4[a]	10.1[a]	34.0	11.9	2.16[a]
- 10.0 tons CaO/ha	45.0[b]	9.88[ab]	30.8	11.1	1.97[b]
F(A)	*	ns	ns	**	**
F(B)	*	*	ns	ns	**
CV_A(%)	3.50	3.10	17.0	6.10	18.7
CV_B(%)	5.60	1.50	8.80	11.9	15.8

ns = non significant difference ($p \geq 0.05$). ** significant difference ($p \leq 0.01$).

The highest maize biomass (165 gr/plant), which was obtained by the M2a treatment (5.0 tons CaO per ha), followed by M3a treatment (159 gr./ plant) and the minimum biomass reached by 153 gr/plant in the M1a treatment (without lime amendment). There were significant differences at 5% level. Similar to the mung bean biomass, the mung bean biomass of the MB2a treatment (5 tons CaO/ha) was the highest value (52.4 gr/plant), which was significant differentces at 5% compared with the MB1a (without lime amendment) treatment (47.7 gr./plant), the MB3a treatment of 10 tonsCaO/ha (45.0 gr/plant and significant differences at 5% (Table 6). Results of Table 6 presented that 100 seeds weight of mung bean raised significantly (at 5% level) with raising different rates of lime from 0.0, 5.0 and 10.0 tons CaO/ha. However, 100 seeds weight of maize was insignificantly affected by the lime amendment. The highest increase of 100 seeds weight of mung beans at MB2a treament (10.1 gr) and the lowest value (9.77 gr) of MB1a of the without lime treatment (Table 6). Results of Table 6 were shown that number of maize and mungbean pods per plant were insufficiently affected by different lime levels. However, number of seeds per pod of maize was sufficiently affected at 5% level except number of mungbean pod. The mungbean and maize production was significant affected at $P<0.01$. The maize and mungbean ranged from 8.2 to 9.7 ton/ha and 1.87 to 2.16 ton/ha respectively (Table 6). The maize yield was obtained the highest value (10.8 tons/ha) at the M2a treatment (supply of 5.0 tons CaO/ha), followed by M3a (10 tons CaO/ha) and the lowest value M1a (8.2 tons/ha) without lime application. Similarly, the mungbean yield of MB2a (5.0 tons CaO/ ha) was the highest value, followed by MB3a (10 tons CaO/ha) and the lowest value of no lime amendment treatment (MB1a) (Table 6). The As contimanated soil could check the growth and yield of crops and were watered by As contaminated waters (Dixit et al., 2016; Kramar et al., 2015). The pH increase of agricultural soils aims to reduce the motion of soil As element and increase crop yield by the lime application (Rosilawati and Shamshuddin, 2014). Application of different lime ratios has sufficiently been positive impacts on soil, matureness and production of crops. However, high lime amendment that may increase strongly soi pH (>7.5) inhibit the growth plants because of unadaptable pH (Minasny et al., 2016; Dora Neina, 2019). There raised the rice yield above 23% when applying for 6.0 tons CaO combined with NPK fertilizer compared to without lime treatment (Chuong and Cuong, 2021).

4. Conclusion

The research content highlights impacts of crop soil, irrigation water and different lime ratios on As absorptions and yields of maize and mungbean. The As accumulation of mungbean in stems and seeds was higher than that of stems and seeds of maize. The highest effect of As decrease in the stems, seeds and yields of maize and mungbean were attained by Application of 5.0 tons CaO combined with NPK, river water irrigation and planted on the soil outside the dike.The lime amendment of 10 tons CaO per ha raised so high pH of soil, which decreased yield of maize and mungbean. Application of 5 tons CaO combined with NPK and river water irrigation is the perfect technology to lessen the As absorption and raise yield of maize and mungbean in the agricultural cultivation on As polluted soils.

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