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Effect of lime and sawdust on the growth, yield and arsenic uptake of mung beans grown in An Phu alluvium soil

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Abstract

A field experiment was carried out with four treatments and four replications with the aim of ascertaining the effects of sawdust and lime on characteristics of soil, arsenic uptake of mung beans, and yield and yield components of mung beans. The results showed that the lime, combined with sawdust, increased the pH level and arsenic content of the soil. Arsenic content in stems and leaves (95.3 mg/kg) and in seeds (6.33 mg/kg) of the mung beans was lower than that of the control by 31.9% and 49.4%, respectively. The lime–sawdust treatment increased pH and EC in the soil, and the arsenic content in stems and seeds was lower than that of the control treatment by 10% and 49.4%, respectively. The application of lime combined with sawdust reduced the absorption of arsenic and increased the yield and yield components of the mung beans. The highest properties of soil were obtained from use of the lime–sawdust treatment of all measured treatments, and significantly different the highest yield of mung beans from the sawdust and lime 2.45 tons ha-1) and the lowest yield (1.9 tons ha-1) from the control treatment were significantly different.

Key words: *Arsenic, lime, mung bean, sawdust, absorption, alluvium soil, arsenic uptake*

1. Introduction

Mung beans contain highly nutritious elements that render these beans a valuable food source for humans. Mung beans are legumes and have nitrogen fixation capabilities, which are beneficial to the soil and positively affect soil fertility and yield in the following rice crops (Khan *et al.*, 2018). In addition, mung beans contain twice as much nitrogen as other grains contain (Laekemariam and

Worku, 2013). Mickelbart *et al.* (2015) proved that mung beans help fight a number of diseases such as anemia and ailments related to old age, including heart disease, cancer, diabetes and obesity.

Many recommendations advocate for the use of organic fertilizers in place of inorganic fertilizers to improve soil fertility (Khan *et al.,* 2018). Food shortages constitute one prominent cause of malnutrition in the world (Hunger Notes, 2016), and people depend on the availability and quality of food (Keatinge *et al.,* 2011; Popkin *et al.,* 2012). Plant growth is restricted and stressed by very high arsenic contamination in the soil that reduces food quality and leads to deterioration in food quality and crop yield. Arsenic pollution levels in soil have recently become increasingly serious and have reduced the yield and quality of many different plants (Bailey-Serres *et al.,* 2012). Arsenic is an element that is toxic to humans and plants and is present in soil, water and air environments around the world (Alam *et al.*, 2011). Human and nature are the two main causes of arsenic contamination of soil (Steffan *et al.*, 2018). Arsenic is highly toxic and harmful to humans and plants (Agency for Toxic Substances and Disease Registry [ATSDR], 2011) because it inhibits plant root growth and promotes lipid oxygenation (Abbas *et al.*, 2018). Many recent studies have recognized that farmers have used contaminated groundwater to irrigate their crops, thus creating a health hazard for those who eat this contaminated food (Gillispie *et al.,* 2015). The arsenic accumulating in the soil from arsenic contaminated water poses a serious threat to sustainable agricultural systems (Gillispie *et al.*, 2015). An Phu is predominantly an agricultural district, and its people use arsenic-contaminated groundwater to irrigate their crops. About 69.,6% of the total groundwater withdrawn is utilized in the agricultural sector (Chuong, 2016).

Due to intensive farming, Vietnam is known as a heavy consumer of chemical fertilizer. Previous studies have reported that the use of well water contaminated with arsenic caused serious contamination of soil and crops. Chuong and Chinh, 2018 showed that application of lime combined with rice husk ash reduces the absorption of arsenic and increases the soybean yield. The treatment with the lime–rice husk ash combination increased pH and EC in the soil and the lowest arsenic contents of soybean in stems and seeds were 81.0; 27.0 µg/kg, respectively (Chuong and Chinh, 2018). Application of lime combined with rice husk ash resulted in the highest yield (7.59 tons/ha), in comparison to the lowest yield (4.63 tons/ha) in the control treatment.

Biosorption technology, which includes metal removal performance for industrial wastewater, is a highly economical and conventional treatment for metal remediation (Lee *et al.*, 2009). The sawdust is a biological absorbent derived from plants that is capable of removing toxic metals from contaminated water (Lee *et al.*, 2009). The mechanism of sawdust absorption is mainly related to ion exchange reactions: arsenate and arsenite ions are trapped on the surface by the positively charged ions present in the sawdust. 90.2% of arsenic content was mainly removed by relating to ion exchange of three algal biomass (Christobel and Lipton, 2015).

The nitrogen-fixing bacteria in legume roots are particularly stimulated by lime. Lime plays a role in promoting organic matter decomposition of beneficial microorganisms in soil and helping to improve soil fertility, and this substance is responsible for providing calcium to the soil and is essential for most of the beneficial microorganisms that live in soil. Plants cannot grow in acidic soil; therefore, lime fertilization is an indispensable tool that reduces the soil acidity, maintains high yields and improves soil quality to meet the requirements of crops (Kamaruzzaman *et al*., 2014). To illustrate, the growth and yield of peanuts dramatically improved from 9.1% to 30.4% productivity when 5 tons of lime and coconut fiber per hectare were applied lime 5 tons of lime and coconut fiber per ha had a significant effect on the growth and. Productivity of the peanut that increased from 9.10% to 30.4%, compared without liming and coconut fiber. (Chuong, 2018). Some efforts have been made to remove arsenate by biosorption (Mohamed, 2016).

2. Materials and methods

2.1. Description of the study site

The study features an experiment conducted in the town of Long Binh, An Phu district, An Giang province. The experiment was carried out in the field at areas inside the dike with four treatments: NT1 (without lime and sawdust), NT2 (2 tons CaO/ha and without sawdust); NT3 (10 tons sawdust/ha and without lime) and NT4 (2 tons CaO/ha combined 10 tons sawdust/ha) and four replications. The kind of irrigation water (deep well water) × two doses of lime and sawdust (10 tons/ha), with an area of each replicate equivalent to 24 m^2 (6 m × 4 m), planted in a single row with a distance of 50 cm × 30 cm (three seeds were planted per hole); the distance between plants was 30 cm and between rows was 50 cm.

2.2. Experimental Procedures

The field experiment was conducted on four different treatments of lime and sawdust fertilization. The inorganic fertilizer was applied (N, P and K at 40, 60 and 50 kg/ha, respectively) for the entirety of all four treatments. Three germinated mung bean seeds were sown per hole. The water of Mekong Delta river was used to irrigate crops for all treatments. Soil samples were taken before and after the experiment on each treatment, agronomic parameters were monitored by the time of growth. The yield

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and yield components of the mung beans were taken after harvest, and arsenic concentration was determined via the atomic absorption method. The soil was air-dried, mixed well and passed through a 2-mm sieve after the harvest of the samples. The characteristics of the plants and the soil were analyzed in the laboratory at An Giang University.

2.3. Statistical analysis

Data were statistically analyzed, and means were compared by least significant differences (LSD) tests at the 5% level of significance according to procedures outlined by Steel and Torrie using the MSTAT-C computer program.

3. Results and discussion

Table 1. Soil particle size distribution and chemical characteristics at the first of the experiment (n=10)

Soil Analysis		**Soil depth (cm)**		**Soil analysis**		**Soil depth (cm)**	
		0 -20	**20-40**			**0-20**	**20-40**
Mechanical analysis	Sand (%)	5.20	3.10	Available nutrients	Total N (%)	0.130	0.140
	Clay (%)	54.0	65,0		Available P (mg kg^{-1})	50.1	49,3
	Silt (%)	49.8	31,9		Available K (mg kg^{-1})	534	612
	C (%)	1.73	1.13		Total Ca (%)	19.0	20.0
	OM (%)	2.46	2.26		As in soil (mg kg^{-1})	48.2	36.1
	C/N	13.3	16.0		As in deep well water (mg kg^{-1})		579

3.1. Soil properties

The soil pH at the end of the experiment ranged from 7.3 (control treatment) to 7.53 (NT4) and exhibited significant differences among the four groups. The treatment that involved combining lime and sawdust (NT4) yielded the highest pH result (7.53). This result shows that application of lime increased the soil pH due to the lime's carbonate content, echoing the results of Mkhonza *et al.* (2020), who also demonstrated that application of lime to the soil resulted in higher soil pH compared to both control treatments and treatments without lime at a soil depth of 0-20 cm.

The interaction of lime and total soluble salts (EC**)** (Table 2) resulted in significant differences among treatments. The EC value ranged from 210 µS/cm to 230 µS/cm, the latter of which occurred in the group that received the sawdust and lime treatment. This result confirms that application of sawdust and lime increases the EC of soil EC. According to Yuli *et al.* (2016), the soil EC after the application of lime and chicken manure (6 tons/ha) increased by 0.78 µS/cm, from 0.99 µS/cm to 1.77 µS/cm.

The different levels of lime and sawdust application resulted in a range of total nitrogen percent, from 0.136% to 0.183% (Table 2). Maximum total nitrogen was observed under the treatment containing 2 tons CaO/ha combined 10 tons sawdust/ha (NT4), and the minimum concentration appeared in the control group (NT1). This outcome further demonstrated that application of lime and organic matter increases the total nitrogen concentration because of the large supply of carbon and nitrogen present in the sawdust. This change in nitrogen concentration reproduces the findings in Lekhika *el al.*'s *(*2019) study, namely, that application of lime and organic amendment spurs a rise in the N-mineralization rate.

Table 2. Results of Soil chemical analysis at the end of the experiment*

Treatments	Characters						
	pH	**EC ($mS\ cm^{-1}$)**	**Total N (%)**	**Available P ($mg\ kg^{-1}$)**	**Available K ($mg\ kg^{-1}$)**	**Total OM. (%)**	**Total Ca (%)**
Control (NT1)	7.30^{b}	210^{b}	0.136^{d}	45.7^{d}	611^{d}	1.20^{c}	18.4^{b}
Lime (NT2)	7.49^{ab}	213^{ab}	0.156^{c}	60.4^{c}	623^{c}	1.24^{c}	20.3^{a}
Sawdust (NT3)	7.40^{ab}	220^{ab}	0.166^{b}	78.4^{b}	657^{b}	1.45^{b}	18.7^{b}
Sawdust and lime (NT4)	7.53^{a}	230^{a}	0.183^{a}	90.4^{a}	780^{a}	1.57^{a}	21.5^{a}
F	**	*	**	**	**	**	**
CV (%)	1.08	6.4	11.6	25.6	10.4	12.0	7.6

* Values are the mean of four replicates. Means within each column having different letters, are significantly different according to LSD at 5 % (*) and 1% (**) level.

The available phosphorus was maximized (90.4 mg/kg) in the three experimental groups (Table 2). The minimum available phosphorus remained steady at 45.7 mg/kg in the control group. Application of lime and chicken manure increased microbial activity and available phosphorous in highly acidic soils (Simonsson *et al.*, 2018; Lekhika *el al.*, 2019).

The results in Table 2 show that co-application of lime and sawdust increased the soil's potassium concentration as a result of the carbonate and cation content in the soil. The highest available potassium (780 mg/kg) was obtained in the NT4 group, the lowest available potassium (611 mg/kg) was found in the control group. Chuong (2019) likewise observed that the highest available potassium (0.170 meq/100 g) was present in soil that had received 3.5 tons of CaO/ha and 10 tons of cow manure/ha as fertilizer. The above results proved that co-application of lime and sawdust can both increase available K and reduce K leaching in soil.

The soil's organic matter (OM) content ranged from 1.20% to 1.57%, with significant differences among the treatments. The highest value (1.57%) was obtained by the co-application treatment of lime and sawdust (NT4). In contrast, the OM content in the control treatment (1.20) resulted in the lowest value. The organic matter content in the soil after the experiment increased the most when the fertilizer contained cow manure, lime and NPK (Chuong, 2019). Furthermore, different kinds of organic manure and different levels of lime also affect the levels of organic matter in the soil. The application of lime and organic manure in the soil could increase soil organic carbon content because organic manure may The soil calcium concentration in the lime treatments was always higher than in the group without lime treatments. The calcium content ranged from 18.4% (NT1) to 21.5% (NT4), and the significant differences were 1% among different treatments. When lime was applied to the soil, the Ca^{2+} and Mg^{2+} concentrations in the soil increased and produced higher yields of alfalfa (Adônis and Nand, 2010).

The average arsenic concentration in the soil was 48.2 mg/kg in deep soil from 0–20 cm and 36.1 mg/kg in deep soil from 20–40 taken in surveyed areas. Moreover, arsenic concentrations of the deep well water used in crop irrigation was 579 µg/kg. Chuong and Chinh (2018) found that the As concentration of 60 deep well water samples exceeded both Vietnamese and WHO standards (50 µg/L and 10 µg/L, respectively). Farmers of six communes in the An Phu district had used the arsenic polluted water of this deep wells to irrigate their fields (69.6% of six communes).

3.2. Yield and components yield

The mean value of plant height varied from 31.5 to 37.6 cm at 20 DAS (Table 3). Among treatments, from 20 DAS to harvest, the greatest plant height was obtained in the NT4 group, and the second-greatest appeared in group NT2. However, there were significant differences due to treatment influence. The lowest plant height was recorded for the NT1 group at all of DAS. The highest plant height obtained under NT4 and NT2 was at 45 DAS, 60 DAS and harvest.

Table 3. Effects of liming and sawdust application on the plant height of meangbean

Treatment	Plant height (cm)			
	20 DAS	45 DAS	60 DAS	Harvest
Control (NT1)	31.5^{b}	55.7^{d}	58.4^{d}	57.6^{d}
Liming (NT2)	35.1^{ab}	64.0^{b}	66.5^{b}	66.4^{b}
Sawdust (NT3)	33.7^{b}	61.4^{c}	63.5^{c}	64.3^{c}
Sawdust and liming (NT4)	37.6^{a}	67.3^{a}	69.7^{a}	70.2^{a}
F	*	**	**	**

CV (%)	9.1	7.17	7.0	7.3

* Values are the mean of four replicates. Means within each column having different letters, are significantly different according to LSD, 5% (*) and 1% (**) level. DAS:days after sowing

Table 4. Effects of liming and sawdust application on yield and yield components of mungbean

Treatment	100-grain weight (g)	No. of pods $plant^{-1}$	No. of seeds pod^{-1}	Grain yield (ton ha^{-1})
Control (NT1)	15.3^{b}	19.3^{d}	6.0^{d}	1.90^{c}
Liming (NT2)	16.5^{a}	21.3^{b}	8.0^{b}	2.15^{b}
Sawdust (NT3)	16.3^{a}	20.4^{c}	7.2^{c}	1.97^{c}
Sawdust and liming (NT4)	16.8^{a}	23.3^{a}	9.0^{a}	2.45^{a}
F	**	**	**	**
CV (%)	4.0	7.3	15.9	11.0

* Values are the mean of four replicates. Means within each column having different letters, are significantly different according to LSD at 1% (**) level.

Table 4 demonstrates that there were significant effects of lime and sawdust treatments on all studied traits of yield and yield components. All studied yield characteristics increased gradually, in ascending order, in the control, lime, sawdust, and lime–sawdust groups. The differences among levels were significant for all traits: lime combined with sawdust at (2 tons CaO/ha + 10 sawdust/ha) produced the maximum number of pods/plant (23.3), seeds per pod (9.0), weight of grain per ha (2.45 tons/ha) and 16.8 g/100 grains.

The mung bean yield ranged from 1.9 (NT1) to 2.45 tons/ha (NT4); it is also worth noting that NT3 resulted in a yield of 1.97, only slightly higher than that of NT1. The different yields of mung beans in the present study depended on the production system. Dinesh *et al.* (2017) recommended that application of 200 kg lime/ha and organic fertilizer reduced soil acidity and increased yield of green beans in the Vindhyan region of India.

3.3.Arsenic uptake

The results presented in Table 5 show that there were significant differences, at 5%, among treatments of As concentrations in the soil prior to and following the experiment. The highest As concentration in soils before the experiment was 33.6 mg/kg, and the lowest was 31.6 mg/kg. These values underscore the alarming overabundance of As in the cultivated land in the An Phu district. In addition, the As content in the soil after the experiment had a statistically significant difference at 5%; the highest concentration of As (46.6 mg/kg) occurred in group NT4, the lowest occurred in group NT1 (34.7 mg/kg), and the concentrations for NT2 and NT3 were 44.5 mg/kg and 37.1 mg/kg, respectively.

Table 5. Effects of liming and sawdust application on A concentrations in the experiment soil (Long Binh, April, 2019)

Treatment	Arsenic in the experiment soil (mg kg^{-1})	
	Before	**After**
Control (NT1)	31.6^{c}	34.7^{d}
Liming (NT2)	33.5^{a}	44.5^{b}
Sawdust (NT3)	32.9^{b}	37.1^{c}
Sawdust and liming (NT4)	33.6^{a}	46.6^{a}
F	*	*
CV%	2.78	14.0

* Values are the mean of four replicates. Means within each column having different letters, are significantly different according to LSD at 5% (*) level.

The results in Table 6 indicate that As concentration in the stems and seeds of mung beans to which the lime and sawdust treatments were applied is lower than that of the control treatment. In NT4, As accumulation in mung bean stems and seeds of mungbean is (95.3 and 6.33 mg/kg) was lower than 0.5 in stems and 2.0 times in seeds than in non-lime treatments. Arsenic concentration of lime or sawdust treatments decreased on average from 0.5 to 1.5 times from the control treatment values. The highest As concentration in stems and seeds (140 and 12.5 mg/kg) appeared in NT1.

Table 6. The effects of sawdust and liming concentration on As in seeds and stems of mungbean grown inside the dike, (Long Binh, April, 2019)

Treatment	As concentrations in parts of plants (mg kg^{-1})	
	Stems	**Seeds**
Control (NT1)	140^{a}	12.5^{a}
Liming (NT2)	107^{c}	8.4^{c}
Sawdust (NT3)	114^{b}	11.0^{b}
Sawdust and liming (NT4)	95.3^{d}	6.33^{d}
F	*	*
CV(%)	16.6	20.7

* Values are the mean of four replicates. Means within each column having different letters, are significantly different according to LSD 5% (*) level.

Many previous studies have shown that the application of lime and organic fertilizers, which has long-term positive effects on soil physics, increased soil fertility and plant nutrients such as total N, available P and available K (Haynes and Naidu, 1998). Lime and organic matter were responsible for reducing EC in acidic soils. Soil EC and pH levels were increased by the presence of mineral salts and $CaCO_3$ when lime and manure were applied (Agus *et al.*, 2008). In the present study, the value of lime and sawdust treatments of soil pH, total nitrogen, available phosphorous, available potassium, total organic matter and total calcium increased without lime and sawdust. In contrast, the soil and the deep well water were polluted by arsenic; the As concentration in both sources exceeded the maximum allowed standard by one to two times. The As contaminated deep well water was mainly to irrigate crops in Long Binh, where a high rate of farmers (90%) used the contaminated water. The average As concentration of deep well water was 297 µg/L (Chuong, 2016).

Lime and sawdust fertilizer are important factors in achieving better growth and development of the reproductive organs of mung beans, and these components result in increases of photosynthesis rate, photosynthetic matter production, yield components and seed yield. Lime and sawdust treatments significantly affected all studied characteristics in this study (Table 4).

Application of lime and sawdust treatments reduced the uptake of As in the stems and seeds of mung bean plants, so As was retained more in the soil than in the control treatments. Therefore, As in the soil in the control treatments was absorbed by stems and seeds of mung beans. This study shows that the soil in this area is seriously contaminated due to the As-heavy deep well water used in irrigating the land for cultivation. The soil As concentration exceeds the allowed concentration in agricultural soil of 12 mg/kg. According to Chuong and Chinh (2020), the protective dyke against floods in An Phu has resulted in a lack of river water for irrigating crops. Farmers in 69.6 % of six communes had to use the As-contaminated deep well water instead of river water for the past five years (Chuong and Chinh, 2018). Long-term use of polluted water for irrigation of crops increased arsenic concentrations in the agricultural soil (Meharg and Rahman, 2003).

Lime combined with sawdust effectively reduces the As that has accumulated in plants. All growth parameters were improved when mung bean plants received the advantageous effects of lime and sawdust. Moreover, additional mung bean growth stemmed from a combination of lime and sawdust. Continued application of lime and other organics enhanced growth and reduced the need to resort to chemical fertilizers and pesticides; the reduced arsenic absorption in mung bean stems and seeds is an example of proper conservation and sustainability. Prior studies further showed that reduc arsenic absorption in up to 98.8% of mung beans is possible through surface ion adsorption of sawdust and precipitation of lime (Sandip *et al*., 2017; Chuong and Chinh, 2018, 2020).

4. Conclusion

Application of lime combined with sawdust improved soil fertility and reduced arsenic absorption by 31.9% in the stems and by 49.4% in the seeds of mung beans. The yield of mung beans increased by 22.5% over the yield of the seeds planted in soil with no added lime and sawdust. Additional in-depth studies are needed to identify with greater clarity the mechanism of reducing As uptake into plants and removing As from agricultural soils.

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