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Uptake of Nutrients in Vegetables Grown on FGD-Gypsum-Amended Soils

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ABSTRACT

This research evaluated the effects of using flue gas desulphurization gypsum (FGDG) for growing of some agronomic crops. The FGDG was added to soil at 0, 2.5, 5.0 and 7.5% by weight. The test plants, Chinese kale and green bean, were grown and harvested after 45 days and 60 days, respectively. Application of FGDG at all ratios significantly increased pH of the soil, due to the lime containing in FGDG. The heavy metals content in plants grown in the FGDG treated tanks were not significantly different from those of the control tank. From the ten studied elements in Chinese kale and green bean seed tissues (As, Ca, Cd, Cr, Cu, K, Mg, Na, Pb, and Zn), the content of five toxic elements (As, Cd, Cr, Cu, and Pb) were very low and not significantly influenced by FGDG, while the content of some nutrient elements (K, Ca, Mg) in the plant tissues growing in FGDG treated soil were higher than the control. Concentration of some micronutrients (Cu and Zn) in plants decreased with increasing dose of FGDG. There has not been any negative effect from applying up to 5.0% FGDG in soil. The results showed possibility of using FGDG as soil amendment in terms of agricultural production and safety.

Key words: FGDG, Vegetable, Nutrients, Heavy metals.

Lignite is the important fuel for electricity production in Thailand. The reserved amounts are high and it is economical and socially acceptable. Flue gas desulfurized gypsum (FGDG) is a major by-product of various types of lignite power plants resulting from scrubbing process for reduction of flue gas discharge sulfur dioxide into the atmosphere. FGDG mainly contains SO_2 reaction products such as gypsum ($CaSO_4$eÿ2H_2O).

In Thailand, the biggest thermal power generated plant is in Northern region, it uses lignite as a combustible fossil fuel. The average sulfur content of lignite mines is 3.2%. Approximately 17.5 million tons of lignite, are supplied to the power generating unit. Over 500,000 tons of sulfur dioxide were emitted, when the plant operated at full covering without emission contact[1,2].

At present, due to the increase of power demand the amount of FGDG from the power plant increases continuously. This leads to the shortage of on-site dump storage space and environmental problem to the surrounding area and it has a negative impact on aquatic and terrestrial systems through runoff[3,4]. Nevertheless, FGDG is relatively high purity[5], it is higher in calcium and sulfur and contains lower amounts of heavy metals. Considering, the main chemical composition of FGDG, it has been used as an economical conditioner for agriculture soils[3, 4,6]. But one side effect of FGDG application is the enhancement of leaching of some metal ions and environmentally sensitive elements in soil. Because the level of trace elements content in lignite fuels is determined by the difference in the quality of the coal origin, its rank and geological history. Although FGDG has been shown to increase crop product, it may contain certain trace elements at injurious level; to plants and the food-chain[7,8]. Some researchers have used FGDG as soil amendments in non-alkali soil. Nevertheless, FGDG is an excellent source of micronutrients essential for plant growth, particularly boron (B) and sulfur (S)[9-11].

Several studies have grown a variety of plants on FGDG amended soils in pot or field studies in order to investigate the effect of FGDG in soils on heavy metal availability and metal uptake by plants (corn, wheat, grass, cane, tomato etc.) [14-15]. But information about the effects of FGDG on phytoavailability of metals of vegetables is limited[16]. Farina and Channon (1988), Shainberg et al. (1989), and Pavan and Bingham (1986) showed that the applications of gypsum significantly increased calcium, and sulfur levels, while magnesium content was significantly decreased[17-19]. Information about FGDG effects on plant growth needs to be evaluated if it will be used for soil amendment. The objective of the present work is to study the effect of FGDG application to soil on the uptake and bioaccumulation of some nutrient metals and heavy metals in some vegetables (Chinese kale and green beans). Soil was mixed with various amounts of FGDG as a source of plant nutrients and subjected to mesocosms experiment (tank experiment)[20]. The aim of the research is to evaluate the feasibility of using FGDS as soil amended material for agricultural production.

MATERIALS AND METHODS

FGDG and soil sample

FGDG samples were collected from the lignite power plant, Lampang province. Sample collection was carried out from dump waste, obtaining third different samples that were mixed and homogenized to give a single sample. Those samples were analyzed for their elemental compositions by Atomic Absorption Spectrometric techniques[5]. The paddy field soils at 0-to 20-cm depth were collected from TakFa district, Nakornsawan province (Soil 1) and Samko district, Ang-thong province (Soil 2) and used to make the various amendments for experimental studies. The soils in these areas are generally characterized by low water availability and this can alter the rate of organic matter mineralization and thus the availability of trace metals. The samples were transported in polyethylene bags to laboratory and air-dried. After drying, the soil samples were ground in a hammer mill and passed through 2 mm sieve.

Tank experiments

The experiment consisted of the evaluation of 3 different FGDG treatments (0(control); 2.5, 5.0 and 7.5 %) by weight added to soil separately and mixed thoroughly with the soil samples. The mixed soils incubation were carried out for 30 days in a greenhouse in a completely randomized distribution for each soil at ambient temperature and free ventilation[20]. The soils were irrigated to keep the moisture by spraying water. After that, the mixed soils were conducted in round cement tanks (80 I.D. X 50 cm height). Each tank was filled with the soil samples to 30 cm depth. In each tank Chinese kales or green bean seedlings with two leaves were initially planted and only healthier plants were remained in each tank (Figure 1). All the plants were watered daily and moisture with tap water for the duration of the experiment. Soil samples were taken from tank for chemical analysis. The elemental compositions of soils are summarized in Table1.

After 45 days of growing for the Chinese kale and 60 days for green bean, they were harvested. Plant samples were harvested from the tank by cutting the plants 2 cm above the soil surface and kept in separate polyethylene bags. Afterwards, the non-edible parts were removed and the samples were thoroughly washed first with tap water and then followed by distilled water. Separated the above-ground portion and then oven-dried at 60°C to constant weight. The dried materials were ground using a hand mortar and stored in paper bags for further analysis.

Sample preparation

Plant digestion[21]

The dry ground samples were accurately weighed 1.0 - 2.0 g and put into the tall beaker. Added 20 mL of concentrated nitric acid and 1.0 mL of 30% w/v hydrogen per oxide and pre-digested in a fume hood over night. Place the beaker on the hot plate and digest at 80 °C 2 - 3 hours or until obtaining clear solution. Each sample was digested and analyzed in duplicate. After digestion and cooling, added 20 mL of deionized water and then filtered by using whatman paper No 40 and diluted to 100 mL with deionized water in a volumetric flask.

Soil digestion[21,22]

Soil analyses were performed on samples from all tanks involved in the study. An air-dried soil sample was ground in a mortar and well mixed. Accurately weight (1.0 g) of each sample was taken into a pyrex beaker, three replicates for each sample, and added 12 mL of aqua regia (3 ml HNO_3 + 9 ml HCl) solution after that kept overnight in a fume hood for predigestion. The solutions were heated on the hot plate until fuming and taken near dryness. After cooling, the solution was adjusted to 10 mL by using 1% v/v HNO_3 and filtered through filter paper (Whatman No. 5). The filtrate was adjusted the volume to 50 mL in a volumetric flask by using 1% v/v HNO_3.

For quality control spiked soil and plant samples were used through all analysis. Both plants and soil-digested sample solutions were analyzed by flame atomic absorption spectrophotometer (FAAS) NOV AA 350, Analytik Jena, Germany, Electro thermal atomic absorption spectrophotometer (ETAAS), AAnalyst 800, Perkin Elmer, USA and hydride generation atomic absorption spectrophotometer (HGAAS) HS 60 Hydride system NOV AA 350, Analytik Jena, Germany.

RESULTS AND DISCUSSION

pH and Metals analysis of Soil

FGDG application significantly increased the overall soil pH from 6.60, 5.44 to 6.91 and 6.65 respectively (Table II). This increase would typically be expected given the portion of unreacted lime in the FGDG. Because this FGDG was obtained from the desulfurization unit installed in lignite power plants, they contained small quantities of heavy metals originating in the fly ash produced by lignite combustion. Therefore, one concern of using FGDG as soil amendment is the potential toxicity of the heavy metals to plants and their accumulation in the food chain. The content of metals (As, Ca Cr, Cu, Cd, Fe, Hg, Mn, Mg, Na, Ni, K, Pb, Se and Zn) in FGDG is presented in Table I. Heavy metals contents in FGDG are lower than those that found in the soils (Table II)

The Table II showed that the amount of sodium, potassium and some heavy metals in treated soils were not significantly different from the control soil. It indicated that there was no contribution of these metals from FGDG. However, the amounts of Ca and Mg in all treated soils were increased with the increase of FGDG amounts. It indicated that they came from FGDG.

Table 1: Major, minor and trace elements in FGDG [5]

%		Average(N = 10 samples (mg/Kg)					
Ca	**SO3**	**Na***	**K***	**Mg***	**Fe***	**Mn***	**Zn***
31.42	45.05	108	143	2388	1478	71.25	1.91
Cd	**Cu**	**Cr****	**Pb****	**Ni****	**As*****	**Hg*****	**Se*****
0.24	6.54	33.90	7.84	<0.05	<0.002	<0.002	<0.002

(* = FAAS, ** = ETAAS and *** = HGAAS)

Metals Content in Plants

By using FGDG, the soil's physical and chemical properties may change and they affected to the absorption of each metal by plants. There are many factors affecting micronutrient availability, such as soil pH, organic matter and etc. The FGDG was added to soil at 2.5, 5.0 and 7.5% by weight.

It was found that all rates of FGDG application significantly increased pH of the soil. The metal content in plants grown in each tank was measured and compared with that in plants grown in the control tank. The ten elements, i.e, As, Ca, Cd, Cr, Cu, K, Mg, Na, Pb, and Zn in Chinese kale tissues and Green bean seed tissues were monitored. The results are shown in Table III. It was found that five toxic elements (As, Cd, Cr, Cu, and Pb) in plants were not significantly influenced by FGDG. As can

Table 2: pH and some metals in mixed soils (Soil-1 and Soil-2)

%FGDG	Soil-1 (mg/Kg) (n = 5)										
	pH	Na	K	Ca	Mg	Zn	Cd	Cu	Cr	Pb	As
0(control)	6.60	1100	9140	2503	2167	81.58	0.90	16.62	31.48	29.91	11.82
2.5	6.72	1125	9118	8430	2525	81.19	0.86	17.37	33.04	32.34	12.27
5.0	6.73	1051	8848	16654	2877	77.91	0.72	17.17	34.65	31.10	12.66
7.5	6.91	1011	8618	22574	3269	75.59	0.65	16.16	37.01	31.19	13.31
%FGDG	Soil-2 (mg/Kg) (n =5)										
0(control)	5.44	519	634	3084	1679	33.61	1.31	32.32	55.56	24.76	7.82
2.5	6.11	523	577	8915	1926	33.06	1.13	32.98	57.46	24.89	7.84
5.0	6.35	527	570	14203	2117	30.91	1.21	31.57	58.18	28.43	8.11
7.5	6.65	520	562	21830	2412	29.14	1.34	30.19	59.92	31.19	8.84

Table 3: Metals content in plants in each tank

% FGDG	Chinese Kale (Soil-1) (mg/Kg) (n = 10)									
	Na	K	Ca	Mg	Zn	Cd	Cu	Cr	Pb	As
0 (control)	1463	4351	4318	515	<0.02	7.47	<0.05	4.18	<0.02	<0.02
2.5	1673	4868	4487	476	<0.02	5.14	<0.05	2.76	<0.02	<0.02
5.0	1686	4594	4655	489	<0.02	5.62	<0.05	3.74	<0.02	<0.02
7.5	1898	5240	4831	523	<0.02	5.88	<0.05	3.05	<0.02	<0.02
% FGDG	Chinese Kale (Soil-2) (mg/Kg) (n = 10)									
0 (control)	788	4861	3728	482	<0.02	5.49	<0.05	6.85	<0.02	<0.02
2.5	885	5315	4576	490	<0.02	5.29	<0.05	5.59	<0.02	<0.02
5.0	889	5534	4616	503	<0.02	6.25	<0.05	5.79	<0.02	<0.02
7.5	1100	5542	4877	536	<0.02	7.38	<0.05	4.62	<0.02	<0.02
% FGDG	Green bean seed (Soil-1) (mg/Kg) (n = 10)									
0 (control)	580	13946	1490	1924	112	<0.02	16.27	<0.05	1.71	<0.02
2.5	649	14213	1563	1931	117	<0.02	15.63	<0.05	2.53	<0.02
5.0	816	14956	1604	1940	131	<0.02	15.69	<0.05	3.01	<0.02
7.5	949	15112	1694	1954	123	<0.02	14.19	<0.05	2.37	<0.02
% FGDG	Green bean seed (Soil-2) (mg/Kg) (n = 10)									
0 (control)	70.03	12978	1474	1771	107	<0.02	19.27	<0.05	3.00	<0.02
2.5	75.74	13358	1467	1797	116	<0.02	17.32	<0.05	2.59	<0.02
5.0	77.00	13364	1635	1896	116	<0.02	13.93	<0.05	2.94	<0.02
7.5	85.08	13680	1657	1959	124	<0.02	14.79	<0.05	2.84	<0.02

be seen from the results, heavy metals (As, Cd, Cr, Cu and Pb) contents in plants grown in the gypsum-treated tanks were not significantly different from those in the control tank. This indicates that the gypsum treatment did not result in an increase of metals in the plants. The treatment of FGDG to soil at 5.0% or higher resulted in the higher concentrations of Ca, Mg and K in plants than those of the control case (approximately 9.2%, 3.7% and 5.0% higher, respectively for 5.0% FGDG treatment versus non-treatment). It indicated that these three nutrient elements came from FGDG and the FGDG could be used as a source of nutrient for plants.

Fig. 1: A tank experiment

FGDG can be used as treatment material for soil amended. FGDG can release Ca and Mg to soil. Ca, Mg and K which releasing from FGDG can be uptake by Chinese kale and Green bean. Contents of heavy or toxic metals in the FGDG are low and they did not contaminate in soil and studied plants. Therefore, there have not been any negative effects from applying up to 5.0% FGDG in soil. Addition of FGDG to the soil is not only increase total concentration of the some macronutrients for soil but also the bioavailable pool of these elements for plant.

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