บทความวิชาการดีประจำปี 2548

สถาบันบัณฑิตพัฒนบริหารศาสตร์

Sewage Sludge as Fertilizer in Soybean Production

NIDA PAPER 2005

THE NATIONAL INSTITUTE OF

DEVELOPMENT ADMINISTRATION

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เรียบเรียงโดย

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ประกาศสถาบันบัณฑิตพัฒนบริหารศาสตร์
เรื่อง ผลการคัดเลือกบทความวิชาการดีและบทความวิชาการดีเด่น ประจำปี 2548

ตามประกาศสถาบันบัณฑิตพัฒนบริหารศาสตร์ ลงวันที่ 22 มิถุนายน 2548 ได้ประกาศเชิญชวนให้บุคลากรของสถาบันส่งบทความวิชาการเข้ารับการพิจารณาคัดเลือกเป็นบทความวิชาการดีและบทความวิชาการดีเด่น ประจำปี 2548 ใน 11 สาขาวิชา คือ สาขาวิชารัฐประศาสนศาสตร์ บริหารธุรกิจ พัฒนาการเศรษฐกิจ สถิติประยุกต์ คอมพิวเตอร์และสารสนเทศ พัฒนาสังคม พัฒนาทรัพยากรมนุษย์ เทคโนโลยีการบริหาร ภาษาและการสื่อสาร การจัดการสิ่งแวดล้อม และสาขาวิชาสังคมศาสตร์อื่นๆ โดยบทความวิชาการที่ได้รับการคัดเลือกจะได้รับเงินรางวัล ดังนี้

1. บทความวิชาการดีเด่น ได้รับเงินรางวัล บทความละ 50,000.- บาท
2. บทความวิชาการดี ได้รับเงินรางวัล บทความละ 30,000.- บาท
3. บทความวิชาการชมเชย ได้รับเงินรางวัล บทความละ 10,000.- บาท

สถาบันบัณฑิตพัฒนบริหารศาสตร์ ได้รับบทความวิชาการที่ส่งเข้ารับการคัดเลือกเป็นบทความวิชาการดีและบทความวิชาการดีเด่น จำนวนทั้งสิ้น 9 บทความ เป็นบทความในสาขาวิชาพัฒนาการเศรษฐกิจ 5 บทความ ภาษาและการสื่อสาร 1 บทความ พัฒนาทรัพยากรมนุษย์ 1 บทความ สถิติประยุกต์ 1 บทความ และการจัดการสิ่งแวดล้อม 1 บทความ ซึ่งคณะกรรมการดำเนินงานคัดเลือกบทความวิชาการดีและบทความวิชาการดีเด่นได้พิจารณาบทความดังกล่าวเสร็จเรียบร้อยแล้ว ผลปรากฏว่า บทความวิชาการในสาขาวิชาการจัดการสิ่งแวดล้อม เรื่อง "Sewage Sludge as Fertilizer in Soybean Production" ของ ผู้ช่วยศาสตราจารย์ ธวัชชัย ศุภดิษฐ์ เป็นบทความวิชาการที่ได้รับการคัดเลือกให้เป็นบทความวิชาการดี ประจำปี 2548

จึงประกาศให้ทราบทั่วกัน

ประกาศ ณ วันที่ 3 กุมภาพันธ์ พ.ศ. 2549

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อธิการบดีสถาบันบัณฑิตพัฒนบริหารศาสตร์

Sewage Sludge as Fertilizer in Soybean Production

Tawadchai Suppadit[1]

บทคัดย่อ

การทดลองครั้งนี้มีวัตถุประสงค์เพื่อศึกษาการเจริญเติบโต ผลผลิต องค์ประกอบของผลผลิต คุณภาพของเมล็ด รวมทั้งปริมาณสารอาหารและการสะสมโลหะหนักในถั่วเหลืองพันธุ์เชียงใหม่ 60 ที่มีการใช้กากตะกอนจากโรงบำบัดน้ำเสียชุมชนเป็นปุ๋ยเพื่อทดแทนปุ๋ยเคมีสำหรับพืช ทำการทดลองระหว่างเดือนกุมภาพันธ์-มิถุนายน พ.ศ. 2547 วางแผนการทดลองแบบสุ่มสมบูรณ์ โดยใช้กากตะกอนน้ำเสียชุมชนผสมกับดินในอัตราร้อยละ 0, 5, 10, 15 และ 20 โดยน้ำหนัก และปุ๋ยเคมีสูตร 12-24-12 ในอัตรา 10 กรัม/กระถาง รวม 6 หน่วยทดลอง หน่วยทดลองละ 4 ซ้ำ

ผลการทดลอง พบว่า การเจริญเติบโตของต้นถั่วเหลือง ผลผลิต องค์ประกอบของผลผลิต คุณภาพของเมล็ด และโปรตีนและไขมันของเมล็ดถั่วเหลือง มีความแตกต่างกันระหว่างหน่วยทดลองอย่างมีนัยสำคัญทางสถิติ *($P<0.05$)* การผสมกากตะกอนในอัตราร้อยละ 5 ส่งผลให้ถั่วเหลืองมีสมรรถภาพการผลิต ผลผลิต และองค์ประกอบการผลิตโดยรวมดีที่สุด และดีกว่าการใช้ปุ๋ยเคมีแต่ที่อัตราส่วนต่ำสุดดังกล่าวยังพบปริมาณตะกั่วและปรอทตกค้างในใบและเมล็ดของถั่วเหลืองเกินค่ามาตรฐาน โดยการตกค้างของโลหะหนัก (ตะกั่ว แคดเมียม และปรอท) ในใบและเมล็ดถั่วเหลืองและในดินก่อนและหลังการทดลอง รวมทั้งการสะสมของธาตุอาหารในดินนั้นมีแนวโน้มสูงขึ้นอย่างมีนัยสำคัญทางสถิติ *($P<0.05$)* แปรผันไปตามอัตราการผสมกากตะกอนที่เพิ่มขึ้น สรุปได้ว่า การใช้กากตะกอนน้ำเสียชุมชนทดแทนปุ๋ยเคมีสำหรับการปลูกพืช อาทิ ถั่วเหลือง นั้น ไม่ควรใช้กากตะกอนเป็นแหล่งธาตุอาหารสำหรับพืชที่ใช้เพื่อการบริโภคสำหรับมนุษย์และสัตว์ เนื่องจากอาจเกิดการตกค้างของโลหะหนักในผลผลิตของพืช แต่สามารถใช้เป็นแหล่งธาตุอาหารในการปลูกพืชประเภทอื่นได้ โดยควรใช้ในปริมาณหรืออัตราส่วนที่เหมาะสม เนื่องจากเมื่อภายหลังสิ้นสุดการทดลอง การสะสมของปริมาณโลหะหนักในดินยังอยู่ในเกณฑ์มาตรฐานของดินที่สามารถใช้เพื่อการทำเกษตรกรรมได้

Abstract

This research sought to study the growth, yield, yield components, seed quality, including nutrient and heavy metal content of soybean cultivar Chiang Mai 60 (CM. 60) by using sewage sludge from domestic wastewater treatment as fertilizer. The experiment used a completely randomized design, divided in 6 treatments with 4 replications and was conducted from February to June, 2004. Sewage sludge was mixed with soil at the rate of 5, 10, 15 and 20% by weight, and chemical fertilizer (12-24-12) was applied at the rate of 10 grams/basin.

The results showed that soybean growth, yield, yield components, seed quality, protein and lipid were significant *($P<0.05$)*, showing the best potential productivity at 5% by weight and being better than chemical fertilizer. The residues of heavy metals (lead, cadmium and mercury) accumulated in leaves and seeds, including in soil before and after the study were also significant *($P<0.05$)* related to the quantity of sewage sludge used. Soil nutrients of all treatments were also significant *($P<0.05$)*. The data varied similarly to the residues of heavy metals. The

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replacement of sewage sludge for chemical fertilizer in plant production including soybean could be as a nutrient source. However, it must used in an appropriate rate. Moreover that, it should not be used in plants for human and animal consumption because heavy metals may accumulate in plant products.

Key words : nutrient, potential productivity, heavy metal

Introduction

The extensive communities and industrial developments continue to cause environmental problems from amounts of water waste and pollutions in Thailand (Suppadit, 2003). Domestic wastewater is one of these problems which is related to community growth and population increase. Water pollution is caused by wastewater discharge or leakage, or discharge without control and treatment. In the future, clean water for consumption may not be available in Thailand (Suppadit, 2004). Therefore, the Thailand government tries to improve water quality with the proper operation of wastewater treatment systems. The major aim of wastewater treatment is to remove as much as possible suspended solids before the remaining water is discharged back to the environment. After treatment, sludge content is about 60.0 grams/person/day (Tunnukit, 1999) which differs in type, characteristics, and composition depending on water utilization activities of these communities (Chawsithiwong, 2000). Sludge is composed of organic compounds, nitrogen, phosphorus and potassium at levels of 50.0-80.0, 2.50-5.00, 1.50-2.00, and 0.020-0.500 percent/dry weight, respectively (Suntornvongsagul, 1994). At present management sewage sludge involves discharging it to public lands (Suppadit, 2004) which still has many problems for environment. A new concept for sewage sludge management involves its use as a fertilizer for crop production, including field and vegetable crops (Sermviriyakul, 2004). This study sought to apply sewage sludge to replace chemical fertilizers. This method may decrease the costs of soybean production, improve the environmental health and safety in long-term period and provide evidence for sewage sludge management in a community.

Materials and Methods

Experimental Place

Trials were conducted at Kleang District, in Rayong Province from February to June of 2004. The trials were in an artificial greenhouse that measured 6.00 m wide × 8.00 m long × 2.00 m high (96.0 m^3), and used a plastic roof. Corrugate iron and blue net were used as a border around the greenhouse.

Experimental Design

This study was a separate, completely randomized design with 4 replications. The treatments evaluated are as follows:

T0: Control (without sewage sludge or chemical fertilizer)
T1: Soil mixed with sewage sludge, 5%/(w/w)
T2: Soil mixed with sewage sludge, 10%/(w/w)
T3: Soil mixed with sewage sludge, 15%/(w/w)
T4: Soil mixed with sewage sludge, 20%/(w/w)

T5: Chemical fertilizer formula 12-24-12, 10.0 g/basin, applied after 20 days after emergence (DAE)

Soybean cultivar Chiang Mai 60 (CM. 60) was evaluated. Soil was mixed with dried sewage sludge into total weight 10 kg/basin (T1 - T4). Besides, soil weight of T0 and T5 was 10 kg/basin, which did not mix with sewage sludge. After two weeks, soybean seeds were planted in each plastic basin, thinned one week after, leaving four seedlings/basin. These were watered until the R7 stage (beginning maturity). The entire plots area was weeded by hand. Tobacco was used for insect control. Data recorded were planting date, stage of emergence, number of nodes, height, leaf area, dry matter, number of pods/plant, number of seeds/pod, 100 seeds dry weight, and yield/basin. Seed germination and vigor were recorded based on ISTA Rule (1985). Proteins and lipid were measured by the Kjeldahl method and by extraction, respectively. Heavy metals were measured by using the methods of atomic - direct aspiration for lead and cadmium and atomic absorption - cold vapor for mercury.

SAS program version 6.12 (SAS Institute, 1996) was used for analysis of variance and DNMRT (Duncan's New Multiple Range Test) to compare the experimental treatments.

Results and Discussion

Potential Growth and Yield

The number of soybean nodes was significant for all treatments *($P<0.05$)* (Fig. 1). The highest node/plant of 15.0 nodes was obtained from the 5% mixture which was not different from the chemical fertilizer (14.5 nodes). Similar results were obtained by Srisomboon (1999), who reported 15.0 soybean nodes. The 5% mixture was the optimum for soybean production. Increasing the quantity of sewage sludge caused a decrease in the number of nodes which could be due to the increasing level of heavy metals related to the quantity of sewage sludge used. This may be a factor affecting soybean growth and development. Cationic metals which are more soluble in acid soil appeared in this experiment. These have been found to inhibit plant photosynthesis, decrease plant dry matter accumulation and soil microorganism activities and increase NO-3 accumulation (Panichasakpatana, 1996). Although, the 20% mixture showed the highest value of nutrients, this level showed the lowest number of nodes and had the highest value of soil salinity, which is not appropriate for soybean production.

Soybean height was also significant *($P<0.05$)* and it varied according to the quantity of sewage sludge (Fig. 1). The 5% mixture showed the tallest height attained (79.0 cm.) while the shortest soybean height (49.5 cm) was obtained in the 20% mixture. The reasons were the same as number of soybean nodes.

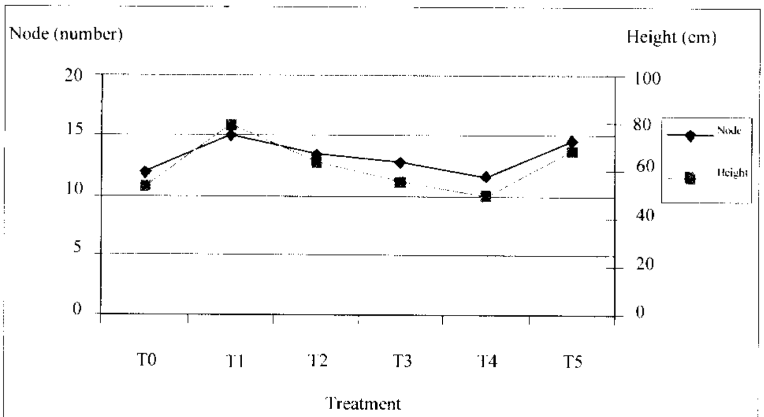

Figure 1. Node and height of soybean cultivar CM. 60 at different levels of sewage sludge and chemical fertilizer

The leaf area of soybeans were significant for all treatments *(P<0.05)* (Fig. 2). At the reproductive growth stage (Fehr and Caviness, 1977) of R1 (beginning bloom; 216 cm^2), R3 (beginning pod; 228 cm^2), R5 (beginning seed; 624 cm^2), the 5% mixture still showed the highest value of leaf areas. Except at the R3 stage, both of the 5% mixture (228 cm^2) and chemical fertilizer (211 cm^2) showed the highest value. The data show that, increasing the quantity of sewage sludge caused a decrease in leaf area. Therefore, at the 5% mixture was also the optimum nutrient for soybean production. Not only that, increased levels of heavy metals inhibited root and leaf growth (Panichasakputana, 1996). The leaf areas showed steady growth from the R1 stage through the R5 stage. These increased slightly from the R1 stage to the R3 stage and after that increased rapidly to R5 stage. Leaf areas of chemical fertilizer treated plants were relative slow at stage R1, but picked up rapidly in stage R3 to R5 because of the effects of the fertilizer application (applied at 20 DAE).

Dry matter of soybean were significant for all treatments *(P<0.05)* (Fig. 3). Their accumulation at stages R1, R3, R5, R7 (beginning maturity) and R8 (full maturity) differed, showing the highest value for the 5% mixture and the lowest value for the 20% mixture. Increasing the quantity of sewage sludge caused a decrease in dry matter for reasons same as for the number of soybean nodes. Similar results were obtained by Sirisukhodom (1992), who reported that, dry matter of Chinese cabbage decreased when these were planted under high conditions of lead and zinc (more than 10.0 and 15.0 mg/kg, respectively). When chemical fertilizer was applied, dry matter accumulated relatively slowly, nearly the same as the 0 and 15% mixture at the R1 stage, but then increased rapidly after the R1 stage and was the second highest value after the 5% mixture. The highest accumulation appeared at the R7 stage but decline slightly at the R8 stage. Similar results were obtained by Pataradilok (1991), who reported that soybean dry matter from cultivar CM. 60 planted in March was 36.3 g which was higher than all treatments. Results showed that the limitations may came from the planting season, location and nutrient uptake. This result is similar to Pookpakdi and Ketngam (1987), who said growth development is derived from environmental factors.

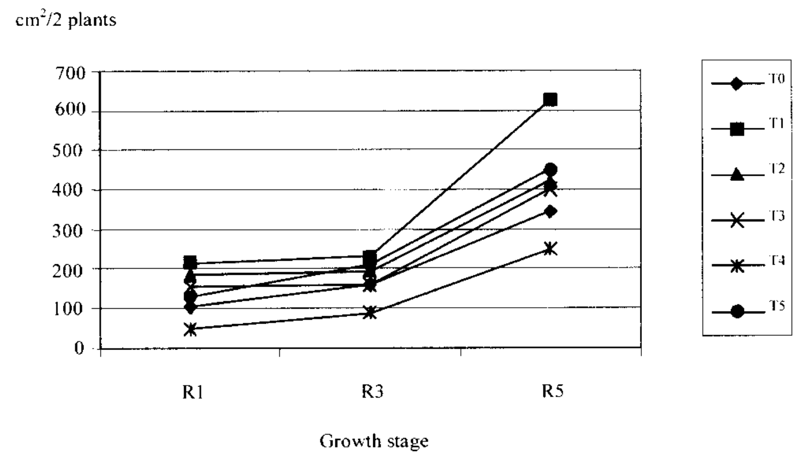

Figure 2. Leaf area of soybean cultivar CM. 60 at different levels of sewage sludge and chemical fertilizer

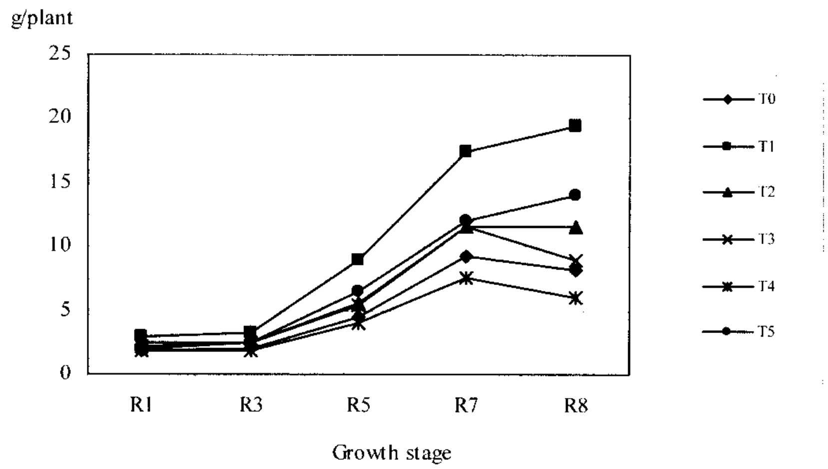

Figure 3. Dry matter of soybean cultivar CM. 60 at different levels of sewage sludge and chemical fertilizer

Yield was also significant for all treatments *(P<0.05)* (Table 1), showing the highest yield/basin for the 5% mixture (49.2 g/basin) and the lowest yield/basin for the 20% mixture (15.9 g/basin). Results for yield/basin was similar to dry matter, varying the same way. Similar results were obtained by Pataradilok (1991), who found that increasing mean of dry matter caused an increase of soybean yield.

Soybean pods were significant for all treatments *(P<0.05)* (Table 1). The highest number of pods/plant was for the chemical fertilizer (41.2 pods) and the 5% mixture (40.2 pods), while the 0, 15 and 20% mixture had lowest number (26.2, 28.0, and 22.0 pods, respectively). Increasing the quantity of sewage sludge caused a decrease of soybean pod. The 5% mixture was the optimum of nutrient for soybean production and increasing the quantity of sewage sludge did not produce more pods/plant. Because the soil was acidic nutrients were in an unavailable form and the plant could not absorb fully the nutrients. Not only that, soybean pods were affected by high levels of heavy metals in the same manner as number of soybean nodes.

Table 1. Yield and yield component of soybean cultivar CM. 60 at different levels of sewage sludge and chemical fertilizer.

Treatment	Yield	Yield component		
	(g/basin)	Pod/plant (pod)	Seeds/pod (seed)^{ns*}	100 seeds dry weight (g)
T0	19.6^{e}	26.2^{b}	1.60	11.7^{e}
T1	49.2^{a}	40.2^{a}	1.90	16.1^{a}
T2	27.6^{c}	32.0^{ab}	1.70	12.7^{c}
T3	22.3^{d}	28.0^{b}	1.70	11.8^{d}
T4	15.9^{f}	22.0^{b}	1.60	11.4^{f}
T5	41.4^{b}	41.2^{a}	1.90	13.5^{b}
% CV	0.0300	23.9	13.70	0.170

Means in the same column with different superscripts are significantly different at *P<0.05*.

*Not significantly different

The number of seeds/pod was not significantly different for any treatment *(P<0.05)*, although the 5% mixture and chemical fertilizer showed the highest number of seeds/pod (1.90 seeds) (Table 1). The results agree with Pookpakdi and Ketngam (1987), who reported the number of seeds/pod is controlled by genetic characteristics more than environmental conditions. Thus, sewage sludge and chemical fertilizer did not affect the number of seeds/pod.

The weight of one hundred seeds was significant for all treatments *(P<0.05)* (Table 1). The 5% mixture still showed the highest one hundred seed weight (16.1 g), while the 20% mixture had the lowest (11.4 g). These data are similar when compared with Srisomboon (1999), who reported seed weights of 15.0-17.0 g. Increasing the quantity of sewage sludge caused a decrease in seed weight. The results varied similarly to soybean pods.

Seed Quality

The effect of sewage sludge on germination and on seed vigor in the laboratory were significant for any treatments *(P<0.05)* (Table 2). The 5% mixture showed the highest percentage while the 20% mixture resulted in the lowest. Increasing the quantity of sewage sludge caused a decrease in seed quality which may be due to heavy metals affecting seed germination and vigor.

Seed protein of all treatments were significant *(P<0.05)* (Table 2). The 5% mixture showed the highest value (39.3%) and the 20% mixture showed the lowest value (32.4%). Seed lipid were also significant *(P<0.05)* (Table 2). The data varied similar to seed protein. Values of all treatments were all less than Chiang Mai Field Crops Research Center report (Chiang Mai Field Crops Research Center, 2000), which reported 43.8 and 20.0% for protein and lipid in soybean cultivar CM. 60, respectively. Increasing the quantity of sewage sludge caused a decrease in seed protein and lipid. The difference came from climate conditions, environmental limitations, planting season, and variety. Panichasakpatana (1996) reported that heavy metals inhibited soybean growth and development, delayed seed emergence, and decreased seed protein and lipid.

Table 2. Seed quality, protein and lipid content of soybean cultivar CM. 60 at different levels of sewage sludge and chemical fertilizer.

Treatment	Germination (%)	Vigor (%)	Protein (%)	Lipid (%)
T0	34.0^{d}	15.0^{d}	29.2^{f}	9.80^{f}
T1	50.0^{a}	38.0^{a}	39.3^{a}	15.1^{a}
T2	39.0^{c}	26.0^{c}	34.7^{c}	14.1^{c}
T3	18.0^{e}	8.00^{e}	32.7^{d}	12.7^{d}
T4	15.0^{e}	6.00^{e}	32.4^{e}	12.4^{e}
T5	44.0^{b}	32.0^{b}	36.0^{b}	14.9^{b}
% CV	7.18	2.77	0.110	0.0900

Means in the same column with different superscripts are significantly different at *P<0.05*.

Heavy Metals Content

In sewage sludge and mixed soil

Sewage sludge contained lead (33.7 mg/kg), cadmium (3.42 mg/kg) and mercury (0.0410 mg/kg). After mixing the soil with sewage sludge, each quantity of heavy metal varied and was significant for all treatments *($P<0.05$)*. Lead in the mixed soil content ranged from 28.7 to 29.7 mg/kg, cadmium was 1.60 to 1.94 mg/kg, and mercury was 0.0301 to 0.0322 mg/kg for all treatments, respectively (Table 3). Heavy metal levels before experiment was not greatly different, because soil contained some part of heavy metals already and the experiment used low rate of sewage sludge. After the experiment, lead in mixed soil 6.90 to 10.0 mg/kg was significant *($P<0.05$)* (Table 3). Treatments at 15 and 20% had the highest lead content (10.0 mg/kg). Cadmium was only significant in the 10, 15 and 20% mixture *($P<0.05$)*. The 20% mixture still showed the highest value (0.200 mg/kg) while the lowest was for the 5% mixture and chemical fertilizer treatments. Mercury ranged from 0.0187 to 0.0227 mg/kg, showing the highest value in the 20% mixture (0.0227 mg/kg). Although the heavy metals seem serious, their quantities, even before the experiment, were not more than the standard set for soil (Panichasakpatana, 1996). Standard range are lead: 0.100-30.0; cadmium: 0.100-2.00; and mercury: 0.100-1.00 mg/kg, as reported by Panichasakpatana (1996).

In plant

Table 3 shows data for heavy metal content of leaves at the R5 stage that were significant *($P<0.05$)*. Lead, cadmium and mercury ranged from 7.10-30.7, 0.300-1.30 and 0.0137-0.0267 mg/kg, respectively showing the highest value for the 20% mixture at 30.7, 1.30 and 0.0267 mg/kg, respectively. Standard range in plant are lead: 0.500-3.00; cadmium: 0.100-1.00; and mercury: 0.0010-0.0100 mg/kg, as reported by Panichasakpatana (1996) and Sirisukhodom, (1992). Lead and mercury levels in all treatments were more than standard, while cadmium showed more accumulation than standard for 15 and 20% mixture only. Increasing the quantity of sewage sludge caused the increase in heavy metals accumulation. Similar results were obtained by Tunnukit (1999), who found that sewage sludge from domestic wastewater caused an increase of heavy metals (cadmium, copper, manganese, nickel, lead and zinc) in planting material related to the quantity of sewage sludge used.

The range values of lead, cadmium, and mercury in seed were 4.32-15.6, 0.100-0.900, 0.0107-0.0207 mg/kg, respectively. Decreasing the quantity of sewage sludge caused a decrease in heavy metals. Heavy metals in seeds were also significant for all treatments *($P<0.05$)*, the 20% mixture had the highest levels; 15.6, 0.900, and 0.0207 mg/kg for lead, cadmium, and, mercury, respectively (Table 3). In addition to the 20% mixture, the 15% mixture also equaled the highest level of cadmium (0.900 mg/kg). Lead and mercury for all treatments were also more than standard, while cadmium showed in the normal level. Increasing of the quantity of sewage sludge caused the increase heavy metals accumulation. The results agree with Champrasert (1984), who reported that, increasing the quantity of sewage sludge caused an increase in cadmium accumulation. This could be from the organic degradation in sewage sludge that produced ammonia compounds and protein ions. Soil had begun to turn acidic and heavy metals became more available. So, heavy metals were absorbed throughout the plant.

It concluded that, soybean leaves accumulated more heavy metals than soybean seed. USDA. NRCS. (2004) reported that, plants had more translocated quantities of metals to their leaves than fruits or seeds. Similar results were obtained by Sirisukhodom (1992), who found kale accumulated more heavy metals in the roots than in the leaves and stem. The same results were obtained by Panichasakpatana (1996), which reported cadmium was most accumulated in roots than leaves and seeds.

Table 3. Heavy metals in mixed soil before and after experiment, soybean leaf (R5), and soybean seed (R8).

Treatment	Mixed soil (mg/kg)*						Soybean leaf (mg/kg)			Soybean seed (mg/kg)		
	Before			After								
	Lead (Pb)	Cadmium (Cd)	Mercury (Hg)	Lead (Pb)	Cadmium (Cd)	Mercury (Hg)	Lead (Pb)	Cadmium (Cd)	Mercury (Hg)	Lead (Pb)	Cadmium (Cd)	Mercury (Hg)
To	28.7^{e}	1.60^{e}	0.0301^{e}	6.90^{e}	Trace	0.0187^{f}	7.10^{f}	0.300^{e}	0.0137^{f}	4.32^{f}	0.100^{d}	0.0107^{f}
T1	29.0^{d}	1.69^{d}	0.0306^{d}	8.30^{c}	Trace	0.0201^{d}	12.6^{d}	0.400^{d}	0.0178^{d}	4.50^{d}	0.300^{c}	0.0137^{d}
T2	29.2^{c}	1.77^{c}	0.0312^{c}	8.60^{b}	0.100^{b}	0.0208^{c}	13.9^{c}	0.900^{c}	0.0209^{c}	5.20^{c}	0.800^{b}	0.0161^{c}
T3	29.4^{b}	1.86^{b}	0.0317^{b}	10.0^{a}	0.100^{b}	0.0213^{b}	14.6^{b}	1.15^{b}	0.0218^{b}	14.4^{b}	0.900^{a}	0.0198^{b}
T4	29.7^{a}	1.94^{a}	0.0322^{a}	10.0^{a}	0.200^{a}	0.0227^{a}	30.7^{a}	1.30^{a}	0.0267^{a}	15.6^{a}	0.900^{a}	0.0207^{a}
T5	28.7^{c}	1.60^{c}	0.0301^{c}	8.00^{d}	Trace	0.0196^{e}	8.20^{e}	0.400^{d}	0.0167^{e}	4.40^{e}	0.200^{d}	0.0118^{e}
% CV	0.100	1.43	0.700	0.280	19.4	0.100	0.280	2.70	0.0800	0.130	2.22	0.120

Means in the same column with different superscripts are significantly different at $P<0.05$.

*Soil of all treatments were sampled from natural planting area, it always contained the quantity of heavy metals.

Conclusions

The growth and yield of soybeans responded to sewage sludge incorporation in soil. Incorporation of sewage sludge at 5% by weight showed the best soybean growth and potential productivity. The use of sewage sludge as replacement for chemical fertilizer in soybean production could be as a nutrient source. However, sewage sludge should not be used at more than 5% by weight.

Suggestions

Application of sewage sludge may cause problems from soil acidity, soil salinity and heavy metals. Thus, soybean growers should check pH and Na - content in sewage sludge and adjust soil pH to 6.5 or higher before actual planting. For heavy metals, further study can be made to monitor bioavailability of heavy metals. Careful plant selection is important for the use of metal - contaminated soils. Plants translocate larger quantities of metals to their leaves than to their fruits or seeds. The greatest risk of food chain contamination is in leafy vegetables like lettuce or spinach. Another hazard is forage eaten by livestock. Flowering plants and ornamental plants are new sectors that can use sewage sludge as fertilizer substitute.

Acknowledgement

Authors would like to express their appreciation for the laboratory support of this work by Mr. Nakarin Pripwai, Chiang Mai Rajabhat University and researchers of Chiang Mai Field Crops Research Center, Thailand.

References

Champrasert, B. 1984. Effect of cadmium in activated sludge to vegetable and some of nutrients. Master Thesis, Kasetsart University, Bangkok, Thailand.

Chawsithiwong, B. 2000. Environment, Ecology and Management. Pathumtip Printing Press, Bangkok, Thailand. 349 p.

Chiang Mai Field Crops Research Center. 2000. Variety of Soybean in Thailand. Somporn Printing Press, Chiang Mai, Thailand. (Leaflet)

Fehr, W.R. and C.E. Caviness. 1977. Stages of Soybean Development. Special report 80. Iowa State University, Ames, IA, U.S.A.

ISTA Rule. 1985. International rules for seed testing. Seed Science and Technology. 13 : 307-520.

Panichasakpatana, S. 1996. Soil pollution from chemical compounds application. In Usa, W. 1998. Nutrient quantity and heavy metal in plant, using waste sludge in soil at Petchaburi Province. Master Thesis, Kasetsart University, Bangkok, Thailand.

Pataradilok, H. 1991. Response of genotypes of mungbean and blackgram to planting dates and plant population densities. Ph.D. Thesis, Kasetsart University, Bangkok, Thailand.

Pookpakdi, A. and S. Ketngam. 1987. Seed growth, yield and nitrogen distribution in various plant components of soybean variety S.J. 4 as affected by different levels of nitrogen fertilizer. Kasetsart Journal. 21 : 390-394.

SAS Institute. 1996. Statistical Analysis System. SAS Institute Inc., North Calorina, U.S.A.

Sermviriyakul, K. 2004. The study of the substitution of sewage sludge for chemical fertilizer in soybean production. Master Thesis, National Institute of Development Administration, Bangkok, Thailand.

Sirisukhodom, S. 1992. Effect of sewage sludge on growth and heavy metal accumulation in vegetables from Pathum Thani agricultural area. Master Thesis, Chulalongkorn University, Bangkok, Thailand.

Srisomboon., S. 1999. Black Seedcoat Soybean Cultivar Sukhothai 3. B.S. Printing Press. Chiang Mai, Thailand. 40 p.

Suntornvongsagul, K., A. Siriratpiriya and P. Sihanonth. 1994. Influence of heavy metals on soil microbial activities and risk of salmonella as a result of sewage sludge utilization in agriculture. Master Thesis, Chulalongkorn University, Bangkok, Thailand.

Suppadit, T. 2003. Environmental Health Management. The Graduate Program in Environmental Management, Center of Graduate Studies Development, National Institute of Development Administration, Bangkok, Thailand. 240 p.

Suppadit, T. 2004. Environment, Ecology and Management. Banpim-Karnpim Printing Press, Bangkok, Thailand. 792 p.

Tunnukit, T. 1999. Effect of sewage sludge as nursery material mixed with top soil and chaff-ash on growth and heavy metal accumulation in seedlings of *Acacia mangium* Wild. *Pterocarpus macrocarpus* Kurz. and *Afzelia xylocarpa* Craib. Master Thesis, Chulalongkorn University, Bangkok, Thailand.

USDA. NRCS. 2004. (August. 8). Heavy Metals Contamination in Soil. (Online). Available URL. : http:// www.soils.usda.gov.

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